

April 17, 1928.

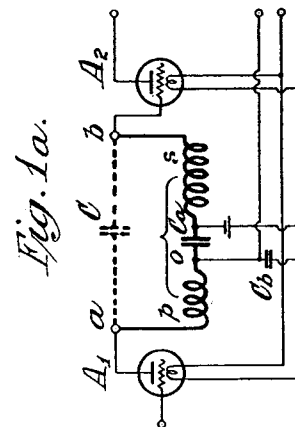
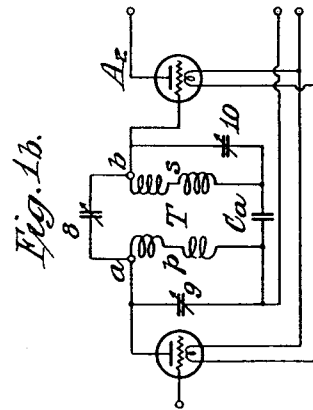
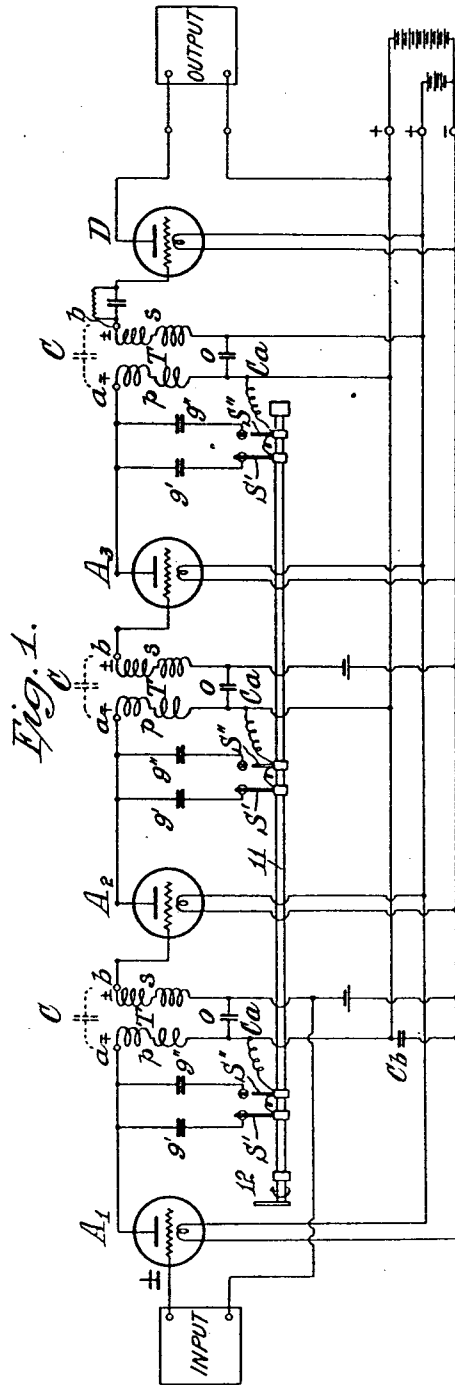
F. K. VREELAND

1,666,518

RADIO FREQUENCY AMPLIFIER

Original Filed Aug. 6, 1923

2 Sheets-Sheet 1



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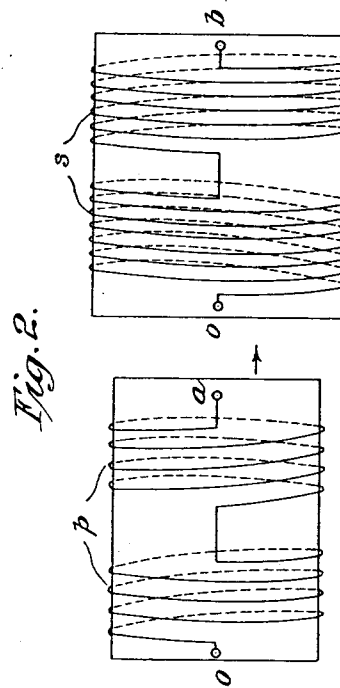
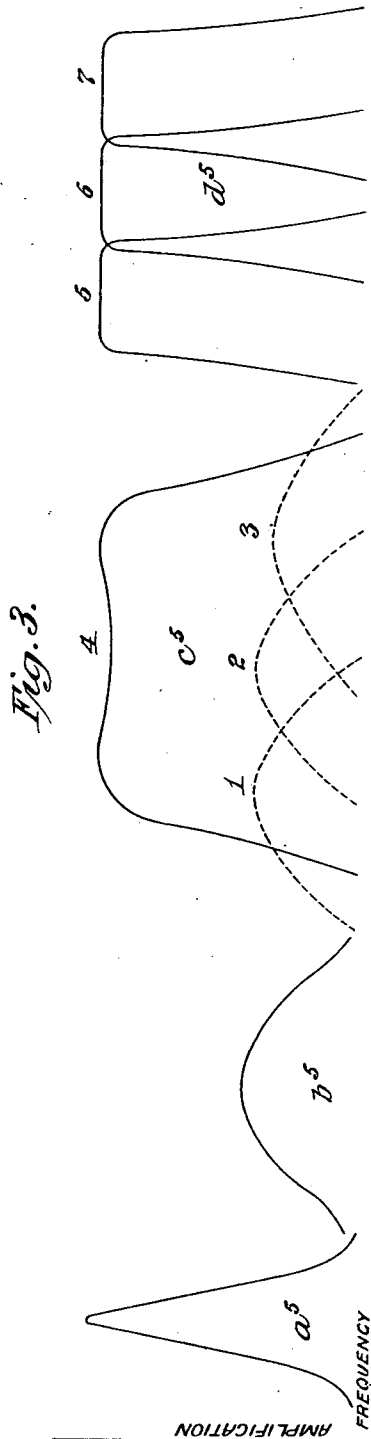
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RADIO FREQUENCY AMPLIFIER

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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE.

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RADIOFREQUENCY AMPLIFIER.

Original application filed August 6, 1923, Serial No. 655,794. Divided and this application filed April 14, 1925. Serial No. 22,928.

The present application is a division of application Serial No. 655,794, filed August 6, 1923.

The invention herein described relates to amplifiers for high or radio frequency currents and is particularly concerned with devices for coupling amplifier tubes in cascade.

In the application Serial No. 655,794, above mentioned, are described the broad features of the invention and several specific modifications. The present application is directed particularly to those phases of the broad invention which relate to the production of a band amplifier and specifically to amplifiers having a controllable band characteristic, including features whereby the amplification is made effective or substantially uniform for all frequencies within a given band or range while frequencies outside of this band are almost completely excluded. It is also directed to those phases of the invention which employ reactances or specifically capacities added to the amplifier coupling means and to the adjustment or change of such reactances or capacities for the purpose of altering the frequency characteristics of the amplifier and particularly for shifting the frequency band over which it operates. It is desirable in carrying out the specific invention of the present application to employ also some or all of the other features set forth in the application above mentioned, although these features are not necessary to the successful operation of the invention.

In the drawings—

Figure 1 is a schematic diagram of a form of apparatus embodying the invention.

Figures 1^a and 1^b show alternative arrangements of certain features of Figure 1.

Figure 2 is a more detailed diagram showing the physical construction of one type of coupling transformer.

Figure 3 shows the amplification characteristics secured by application of the invention.

A particular feature of the present invention resides in the use of a plurality of amplifier units comprising amplifier tubes connected in cascade by suitable coupling means, the several units being so constructed that their individual frequency or selective characteristics are different and preferably overlapping, and so related to each other

that the combined amplifying effect of the system is substantially uniform over a given band of frequencies. The means whereby such individual characteristics are secured and combined to produce a uniform band characteristic, and also the means for shifting the band characteristic in the frequency scale are fully set forth in the following.

In the drawing Figure 1 shows schematically a simple embodiment of the invention, as applied to a radio frequency amplifier of four tubes. In the arrangement shown, three of the tubes A_1 , A_2 , A_3 are used for radio frequency amplification and the fourth D as a detector. When in the following I refer to amplifier tubes generically it will be understood that one of these may be used for detection as shown. T , T , T are transformers coupling the tubes in cascade, each including a primary coil p and a secondary coil s . In the first transformer the outer terminal z of the primary coil p is connected to the output terminal or anode of the first amplifier tube A_1 and the outer terminal b of the secondary s is connected to the input terminal or grid of the second amplifier tube A_2 . The second and third transformers are similarly connected to the second and third amplifier tubes A_2 , A_3 and the detector tube D . The primary and secondary coils are wound or connected in opposite senses so that their outer terminals a and b respectively are at opposite potentials, instead of being at like potentials as is usual in the construction of such transformers. This feature is indicated in the diagram by the sign $\mp$ on the primary terminal a , and $\pm$ on the secondary terminal b , indicating that the polarities of these terminals change in opposite senses.

The windings p , s may be similar, but preferably the secondary is made with more turns than the primary so that a step-up ratio is secured.

To secure the best results it is usually desirable to shunt the external connections of the transformers including batteries, resistances, etc., by bridging condensers such as C_a whose capacity reactance in the working range of frequency is small. These serve to by-pass the high frequency oscillations across the inner terminals of the transformers, avoiding external loss by completing the closed circuit including the windings p , s

and the mutual capacity of the coils by the shortest possible route. Other bridging condensers such as C_6 may be used when desired to by-pass the output current of one tube and the input current of the next to the filament or ground bus.

The preferred arrangement shown in Figure 1 possesses an astatic feature whereby the external field of the transformer is practically eliminated. In this arrangement each of the coils of the transformer is made in two sections, wound or connected in opposite directions so that their external fields oppose and neutralize each other, as fully explained in the application above mentioned. The invention is not limited to the use of any particular construction of transformers or coupling coils for coupling the tubes of the successive amplifier units, although I prefer to employ a transformer coupling of the type here described and illustrated, which produces a system of great stability and freedom from regeneration. I prefer also to employ certain other features of the coupling coils on transformers set forth at length in the application No. 655,794, although the present invention may be carried out with any suitable coupling means. Where coupling transformers are used as shown, a great variety of constructions may be employed, permitting the choice of any desired amplification frequency characteristic for the individual amplifier units and their coupling means, and so providing considerable latitude in the combined or overall band characteristic. Thus by winding the transformer coils with low resistance the apparatus may be made highly selective, so that the transformer circuit with its inherent and associated capacities is resonant to a definite frequency and the amplification is high for this frequency but lower for any other frequency. The individual characteristic curve of such an amplifier unit is shown at a^s Fig. 3 in which the ordinates represent the ratio of amplification and the abscissas represent the frequency. On the other hand, where an amplifier is desired which works effectively over a wide range of frequencies I prefer to wind the transformer coils or particularly the secondary coil of relatively high resistance; for example by winding them of fine copper or larger German silver wire. This resistance has the effect of lowering the peak of the amplification curve without greatly lowering its amplitude at frequencies different from the peak frequency, so that a broad characteristic is secured without corresponding loss in efficiency, as shown for example in b^s Fig. 3.

The degree of coupling between the coils is also an important factor in determining the characteristics of the several amplifier units. Where a broad characteristic is desired I prefer to make the coupling as close

as practicable. Where a sharply selective characteristic is desired a looser coupling is permissible. By suitably proportioning the coupling and resistance as well as the inductance and the mutual capacity of the windings, the characteristics of the amplifier units may be determined at will.

A substantially flat combined or over-all characteristic may be obtained over a desired band of frequencies by the use of amplifier units in cascade having individual characteristics which are different. For example, Figure 3 at c^s shows a typical characteristic of a three-stage band amplifier. The curves in broken lines 1, 2, 3 show the characteristics of the three individual units, including tubes and transformers or other coupling means that are connected in cascade, while the full line curve 4 represents the resultant or overall band characteristic of the combined system.

The different characteristics of the individual units of a band amplifier may be determined by the design of the windings, or characteristics like those shown at 1, 2, 3, Figures 3, c^s , may be obtained from transformers of identical windings by suitably choosing the distance between the coils and the resulting mutual capacity, or by other suitable means.

A convenient means of adjusting the characteristic of a transformer at will is by the use of condensers. Three ways of doing this are shown in Figure 1^b. The first is by shunting an external condenser 8 across the outer terminals of the primary and secondary coils p, s . This external capacity is in effect added to the inherent mutual capacity of the coils, and so lowers the frequency characteristic. The second arrangement consists in connecting a condenser 9 in parallel with the primary coil p . This has a result equivalent to increasing the effective inductance of the primary coil and consequently it lowers the frequency characteristic. A similar result is obtained by connecting a condenser 10 across the secondary coil s but the effect of such capacity is proportionately greater than when the same capacity is added at 9 if, as I prefer, the transformer coils p, s have a step-up ratio.

The condensers or capacities 8, 9, 10 may be used singly or in any desired combination, and any or all of them may be made variable. An effective arrangement for tuning the coupling transformers is secured by designing the transformer to have a sharply selective characteristic and inserting a variable condenser. Figure 1^b shows such variable capacities at 8, 9, 10, and Figure 1 illustrates specifically the location of the variable capacity at 9, 9'.

I prefer to effect this adjustment of the several transformers of the system by a single operation, as shown in Figure 1. These

transformers are preferably designed to have overlapping characteristics as shown at c^5 in Figure 3, giving a combined band characteristic which is flat. This characteristic is shifted in the frequency coordinate by adding impedances to the transformer systems, preferably by the use of small condensers 9' 9'' of suitably proportioned capacity so arranged that they may be shunted successively across the primary coils of the transformers, though it will be understood that the capacities may be added in any of the positions 8, 9, 10 as shown in Figure 1^b. These condensers are cut in and out by switches S' S'' , the switches S' S' S' being arranged to be operated simultaneously, for example, by mounting them on a common rock shaft 11 operated by a handle or lever 12. Similarly the switches S'' S'' S'' operate simultaneously. When the switches S'' are closed by rocking the shaft, cutting in the condensers 9'', the characteristics of all the transformers are changed in frequency so that the combined characteristic is a flat topped band displaced in the frequency coordinate as shown at 6 in part c^5 in Figure 3. The capacity may be varied by the use of additional condensers 9'', which may be switched on by a further movement of the rock shaft 11, closing the switches S'' , and in this way the operating range of the amplifier may be broadened as far as desired. Preferably the capacities of the condensers 9'' 9'' are so chosen that the bands 5, 6, 7 have a slight overlap, as shown.

This arrangement has numerous advantages. An amplifier is secured which gives practically uniform amplification over a wide range of frequencies, and the subdivision of this range into a plurality of narrower bands is useful in eliminating interference from signals of undesired frequencies, since the amplifier is highly effective for frequencies within its band but excludes almost completely frequencies outside of this band. By this means extremely feeble signals may be received without interference from the most powerful nearby stations.

The flatness of the band of effective amplification and the sharpness of the cut-off for frequencies outside this band, which characterize the preferred form of my invention, are secured by so relating the spacing of the characteristics of the several amplifier stages to the width and form of the characteristics as to secure the particular overlap that is required for the characteristic employed. This relation is illustrated in Fig. 3, c^5 , which shows curves for a three-stage amplifier.

Considering the relation of these curves at different frequencies, it is noted that for a frequency less than the peak frequency of the characteristic 1, characteristic 3 shows substantially no amplification and the over-

all characteristic is small. As the frequency is increased, all the component characteristics are increasing simultaneously, and the amplification rises very sharply up to a frequency corresponding to the peak of curve 1. At this frequency curve 1 begins to fall while the others rise more slowly, and, by virtue of the particular spacing employed, the rise of one curve substantially offsets the fall of another, so that the amplification is substantially uniform, up to a point corresponding approximately to the peak of curve 3, beyond which all of the curves are descending. The resultant characteristic descends with a very sharp cut-off.

It will be noted that while all the component characteristics are selective, their cut-off is gradual in the manner that is usual in resonance curves. In the case of the over-all band characteristic 4, however, the cut-off is sharp—much sharper than the slope of the component characteristics—so that the width of the curve at its base is not materially greater than that of the component characteristics, notwithstanding the breadth and flatness of the band at its top.

This is of great importance since it permits a high degree of selectivity due to the sharp cut-off, notwithstanding the width of the band of effective amplification.

The flatness of the band depends upon the spacing. If the spacing is closer than the optimum, the over-all characteristic will be peaked. If the spacing is broader than the optimum, the over-all characteristic will have a central valley. Usually the optimum spacing is secured for a 3-stage amplifier when the high and low frequency characteristics (3 and 1, Fig. 3, c^5) intersect and overlap at a point corresponding to about half the maximum amplification. For other amplifiers the optimum spacing is readily determined by computation or graphic methods.

I claim as my invention:

1. In an amplifier for high frequency currents, a plurality of amplifier tubes, coupling means connecting these tubes in cascade, the several coupling means having frequency characteristics which are different for the several component amplifiers and so related to each other that the combined amplifying effect of the system is substantially uniform over a given band of frequencies, and means for simultaneously adding reactances to the coupling means, thereby shifting the frequency relation of the amplification band while preserving its uniform band character.

2. In an amplifier for high frequency currents, a plurality of amplifier tubes, inductive coupling means connecting these tubes in cascade, the several inductive coupling means having frequency character-

istics which are different for the several component amplifiers and so related to each other that the combined amplifying effect of the system is substantially uniform over a given band of frequencies, and means for simultaneously adding reactances to the coupling means, thereby shifting the frequency relation of the amplification band while preserving its uniform band character.

3. An amplifier for high frequency currents, comprising a plurality of amplifier units including coupling inductances connecting these units in cascade, the units having different amplification-frequency characteristics and in combination producing effective amplification over a band of frequencies, and means for simultaneously adding reactances to the coupling inductances having such values that the amplification band is shifted in frequency while preserving its band character.

4. An amplifier for high frequency currents, comprising a plurality of amplifier units including coupling inductances connecting these units in cascade, the units having different amplification-frequency characteristics, and in combination producing effective amplification over a band of frequencies, and means for simultaneously shunting capacities across the coupling inductances having such values that the band characteristic is shifted in frequency while preserving its band character.

5. An amplifier for high frequency currents, comprising a plurality of amplifier units including coupling transformers connecting these units in cascade, the units having different amplification-frequency characteristics, and in combination producing effective amplification over a band of frequencies, and means for simultaneously shunting capacities across the input and output terminals of the transformers having such values that the band characteristic is shifted in frequency while preserving its band character.

6. An amplifier for high frequency currents, comprising a plurality of amplifier units, coupling inductances connecting these units in cascade, the units having different amplification-frequency characteristics and in combination producing effective amplifi-

cation over a band of frequencies, and means for simultaneously shunting successive increments of capacity across the coupling inductances having such values that the amplification characteristic is progressively shifted in frequency while preserving its band character.

7. An amplifier for high frequency currents, comprising a plurality of amplifier units, coupling transformers connecting these units in cascade, the units having different amplification frequency characteristics and in combination producing effective amplification over a band of frequencies, and means for simultaneously shunting successive increments of capacity across the input and output terminals of the transformers having such values that the amplification characteristic is progressively shifted in frequency while preserving its band character.

8. In an amplifier for high frequency currents, a plurality of amplifier tubes, coupling means connecting these tubes in cascade, the several coupling means having selective characteristics which are different and overlapping, and means for spacing these characteristics in the frequency scale so related to the coupling means as to produce effective amplification over a limited band of frequencies with a sharp cut-off at frequencies outside this band.

9. In an amplifier for high frequency currents, a plurality of amplifier tubes, coupling means connecting these tubes in cascade, the several coupling means having selective characteristics which are different and overlapping, means for spacing these characteristics in the frequency scale so related to the coupling means as to produce effective amplification over a limited band of frequencies with a sharp cut-off at frequencies outside this band, and means for shifting the frequencies of the several characteristics with a similar spacing whereby the band of effective amplification is shifted in the frequency scale while preserving its band character.

This specification signed this 8th day of April, A. D. 1925.

FREDERICK K. VREELAND.