

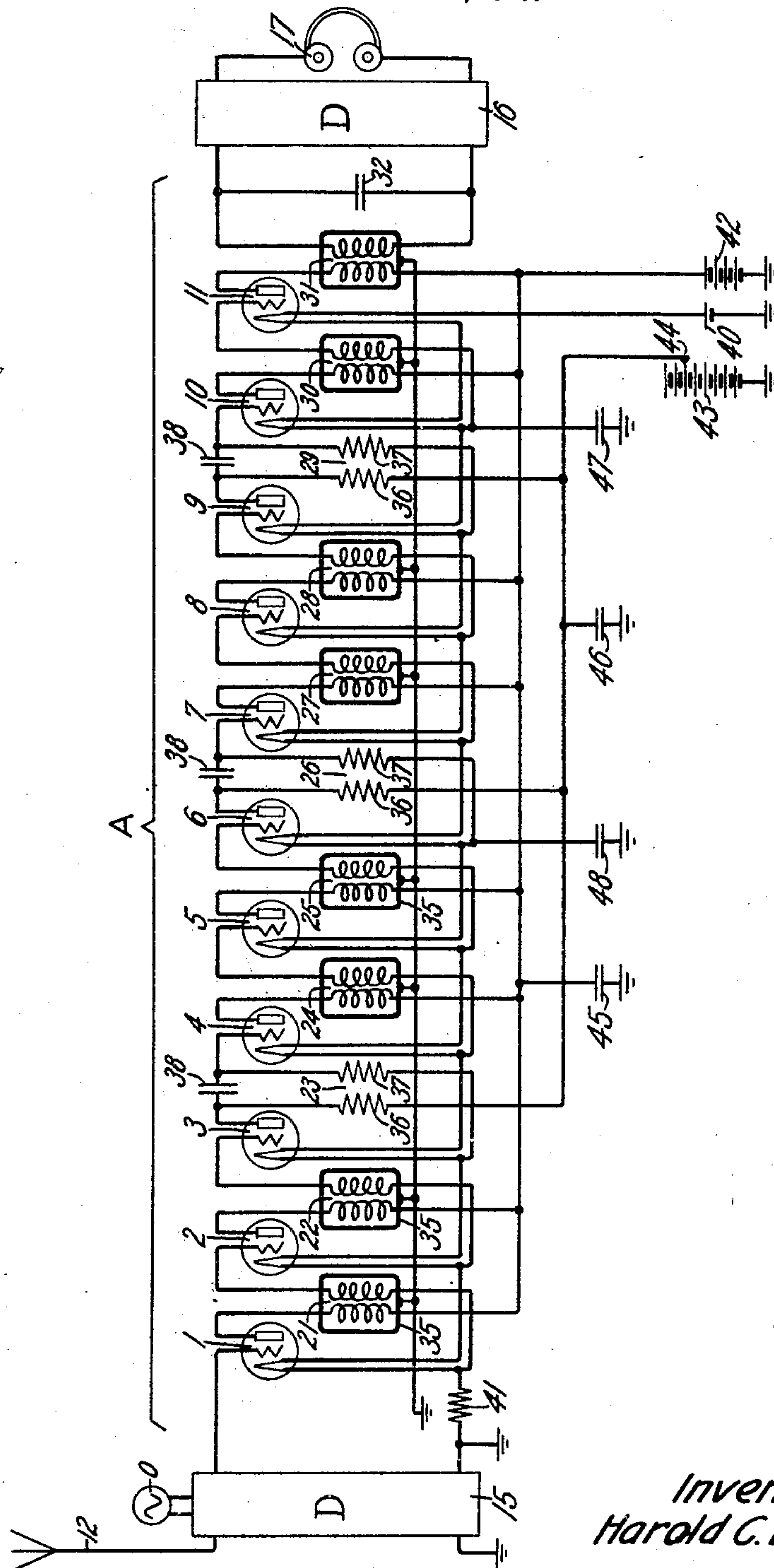
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AMPLIFYING ELECTRICAL VARIATIONS

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AMPLIFYING ELECTRICAL VARIATIONS.

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This invention relates to amplification of electric waves.

An object of the invention is to produce high amplification of high frequency electrical variations without causing disturbance in the amplifying means.

It has been suggested that it is possible to stabilize two high frequency vacuum tube amplifying valves, against singing due to tuned grid and anode circuits, by reducing the efficiency of the coupling between the valves, and that a form of amplifier most suitable for wave lengths over one thousand meters, for which resistance coupling is sufficiently efficient, is a series of tubes with alternate single tuned couplings and resistance couplings.

Where, for example, voltage variations of the order of a million cycles per second are to be highly amplified, a multi-stage vacuum tube amplifier having transformer coupling between stages is desirable, but has a marked tendency to sing.

In accordance, however, with the present invention there is provided an amplifier employing a number of transformer coupled vacuum tube amplifier stages in tandem, and in order to prevent singing in the amplifier, these stages are arranged in tandem connected groups and in the connection between each two groups there is included a vacuum tube stage having a resistance coupling to one of the transformer coupled stages. Each resistance coupling reduces the effect of feed back between the stages which it connects, and makes it possible to continue adding stages until the feed back in these additional stages becomes serious, whereupon another resistance coupling is introduced, and so on. An eleven stage amplifier so constructed has been found to operate satisfactorily at a wave length of three hundred meters, with a voltage amplification of seventy thousand times.

Other objects and features of the invention will be apparent from the following description and claims.

As an example of one specific embodiment of the invention, the single figure of the drawing shows diagrammatically a double detection radio receiving system wherein the principles of this invention are applied to an intermediate frequency amplifier.

In the system shown in the drawing, an

antenna 12, for receiving, for example, radio telephone or telegraph signals transmitted to the antenna as a carrier wave modulated by signal waves of audible frequency, is connected to the input circuit of first detector 15 indicated by block D, the input circuit of the detector constituting a tuning circuit for the antenna. A beating or heterodyne oscillator O is so connected to the detector 15 that the modulated carrier wave, received from the antenna and amplified by the first detector, modulates or is modulated by waves from the beating oscillator. One of the modulation products, the so-called intermediate frequency, is a signal modulated wave of a frequency equal to the difference between the carrier frequency received by the antenna and the oscillator frequency. This difference will ordinarily be small compared to the frequency received by the antenna. This intermediate frequency, in the output circuit of detector 15, may be selected by an intermediate frequency filter, incorporated as a part of the detector circuit, and passed to the input circuit of an amplifier A, of the type referred to above, where as other frequencies may be suppressed by the filter and hence will not be received by the amplifier. The resulting amplified waves are transmitted from the output circuit of amplifier A to the input circuit of a second detector 16, indicated by block D, which detects the amplified wave and derives the audible frequency signal waves therefrom, so that they produce audible sounds in a telephone 17 connected to the output circuit of detector 16. The detector 16, may be, for example, a three electrode vacuum tube detector.

The oscillator O and the first detector 15 including the intermediate frequency filter are preferably of such type, and are preferable so interconnected that they are adapted for the efficient reception of radio signaling waves having frequencies extending up to very high radio frequencies, of the order of forty megacycles and may be of any suitable type. A preferred type is that disclosed in the application of Harald T. Friis, Serial No. 104,619, filed April 26, 1926. With the antenna and first detector input circuit tuned to a frequency f having a value of twenty million cycles, for example, and the oscillator O tuned to a frequency f' equal

to $f \pm 1,000,000$ cycles per second, for example, the intermediate frequency amplifier may have a resonant frequency of one million cycles per second, and a band width of, say, 30 to 50 kilocycles, which is a width sufficient to avoid any necessity for "hair line" tuning at high signaling frequencies.

One advantage of employing such a high intermediate frequency in short wave receivers is that there is thereby obtained a relatively great frequency spacing between the signaling wave frequency and the beating oscillatory frequency, this wide frequency spacing reducing the tendency for undesired reaction between the oscillator and the input circuit of the detector.

The amplifier A comprises eleven stages of three electrode electric space discharge tubes, 1 to 11. The tubes are connected in tandem by couplings 21 to 30, of which every third coupling is a resistance coupling and the others are transformer couplings. The output circuit of tube 11 is coupled to the input circuit of detector 16 by a coupling transformer 31. The input circuit of detector 16 includes a shunt condenser 32. Each of the coupling transformers has a primary winding and a secondary winding, of #38 German silver resistance wire, and tunes with the effective reactance of the input circuit of the succeeding tube at a wave length of about 300 meters. The primary and secondary are wound as a bifilar coil on a wooden spool, the transformers thus having a 1 to 1 ratio. The spool has a diameter of 2" and a width of $\frac{5}{8}$ ", the winding slot being $\frac{1}{2}$ " deep and $\frac{1}{8}$ " wide. The primary and secondary windings are 110 turns each. The transformers are placed in copper cans 35, each 2" x 2 $\frac{1}{2}$ " x 1 $\frac{1}{4}$ ", in order to reduce the effect of the magnetic field.

Each of the resistance couplings comprises a resistance 36 in the plate circuit of the preceding tube, a high capacity direct current blocking condenser 38 connected between the plate of that tube and the grid of the succeeding tube to prevent application of steady potential from the space current source 43 to that grid, and a high resistance 37 forming a direct current conductive grid leak path from the grid to the filament circuit. The filaments of tubes 1 to 11 are all connected to a source of electromotive force 40, in series with each other and with a resistance 41 which is in circuit between the filament of tube 1 and the negative pole of source 40. The grid of tube 1 may be conductively connected to the negative pole of source 40 to obtain a steady biasing potential from the voltage drop across resistance 41 due to the filament heating current. Each of the tubes 1 to 11 has its grid connected, through its grid leak resistance or through the secondary winding of its input transformer, to the low potential end of the fila-

ment of the preceding tube, and therefore obtains steady grid biasing potential from the voltage drop in that filament produced by the filament heating current. Each of the resistances 36, and also each of the resistances 37, has a value of the order of 20,000 ohms. All of these resistances 36 and 37 may be lavite resistances. The condensers 38 may have a capacity of the order of 100 micromicrofarads, and offer negligibly low impedance to waves having lengths of the order of 300 meters.

In the particular amplifier described in detail herein, each of the tubes 1 to 11 may be a Western Electric Company type 215A vacuum tube. A 45 volt source of electromotive force 42 supplies space current for all of the tubes having their plates connected to output transformers. A 67 $\frac{1}{2}$ volt battery 43 supplies space current for the remaining tubes, the voltage supplied to the tubes from this source being adjustable in value, as indicated in the drawing by the movable contact 44 adjustable to different cells of the battery, in order to control the gain of the amplifier. It was found that by thus varying the plate voltage of the tubes having their output circuits resistance coupled to other tubes, the amplifier gain was varied without changing the shape or band width of the transmission curve or resonance curve of the amplifier plotted between the logarithm of the voltage amplification, as ordinates, and frequently as abscissæ. By band width is meant the width of the resonance curve at half of its maximum height.

Condensers 45 and 46 by-pass high frequency around sources 42 and 43 respectively and reduce any tendency to sing which might result from voltage drop across the common battery due to passage of the high frequency current through the battery.

Condensers 47 and 48 connect points of the filament circuit to ground, for high frequency, in order to reduce any tendency to sing due to flow of high frequency current in the filament circuit. The resistance couplings in the circuit also diminish such tendency.

Each of the condensers 45 to 48 may have a capacity of the order of one microfarad.

With a single stage of amplification using the transformer described above, the voltage amplification obtained was 4.5 times, and the band width 700,000 cycles per second. Three stages gave an amplification of over 100 times and with four stages the amplifier went into the singing condition. With two stages of amplification, at 10^6 cycles per second, a small amount of feed back was present, and with three stages considerably more. However, two stages were quite stable. Experiments showed that a single stage resistance coupled amplifier gave an amplification of about unity at one million cycles per

second. Connecting one pair of transformer coupled amplifying stages to another pair of transformer coupled amplifying stages by a resistance coupled amplifier stage
5 eliminated singing and gave an amplification of 360 times, which is merely the proper amplification for four stages assuming that the amplification of the transformer coupled stages was 4.5 times per stage and the am-
10 plification of the resistance coupled stage unity.

Inserting a resistance coupled amplifier between each pair of a number of pairs of transformer coupled amplifying stages, in
15 this manner, an eleven stage amplifier was built, which gave a voltage amplification of 70,000 times with a band width of 50,000 cycles per second.

Specific values have been mentioned above
20 for the purpose of illustration, and the invention is not to be regarded as thereby limited to those values or limited in any other respect except as indicated by the scope of the appended claims.

25 What is claimed is:

1. An amplifier adapted to produce, without singing, high gain at a frequency of the order of at least one million cycles per second having a plurality of amplifier stages
30 in tandem, each of said stages including an electric space discharge device having input and output circuits, said amplifier comprising resistance coupling means coupling two of said devices in tandem, and said amplifier comprising means coupling the input
35 circuit of one of said two devices to another of the devices, said last means and circuit having a natural period corresponding to a frequency of the order of at least one million
40 cycles per second, and said amplifier also comprising means coupling the output path

of the other of said two devices to the input circuit of another of the devices, said last mentioned means and circuit having a natural period corresponding to a frequency of
45 the order of at least one million cycles per second.

2. An amplifier circuit for producing without singing a high gain at frequencies of the order of at least one million cycles
50 per second comprising a plurality of electric discharge amplifiers each having input and output circuits, interstage transformers for coupling said amplifiers in tandem into groups each comprising at least two ampli-
55 fiers, and resistance means connected in shunt to the output circuit of the last amplifier in one of said groups and in shunt to the input circuit of the first amplifier of another of said groups for coupling said groups in
60 tandem.

3. An amplifier circuit for producing without singing a high gain at frequencies of the order of at least one million cycles per second comprising a plurality of electric
65 discharge amplifiers each having input and output circuits, interstage transformers for coupling said amplifiers in tandem into groups each comprising at least two amplifiers, resistance means connected in shunt to
70 the output circuit of the last amplifier in one of said groups and in shunt to the input circuit of the first amplifier of another of said groups for coupling said groups in tandem, and a variable potential source of cur-
75 rent connected to supply space current to said last amplifier of said one group to control the overall gain of the said amplifier circuit.

In witness whereof, I hereunto subscribe
80 my name this 2nd day of June A. D., 1926.

HAROLD C. BAUMANN.