April 4, 1939. K. SCHLESINGER 2,152,823

COUPLING TRANSFORMER

Filed Feb. 24, 1936 2 Sheets-Sheet 1

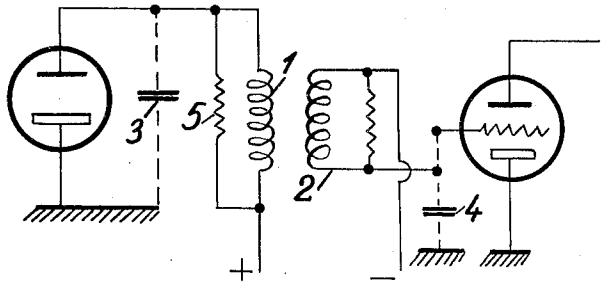
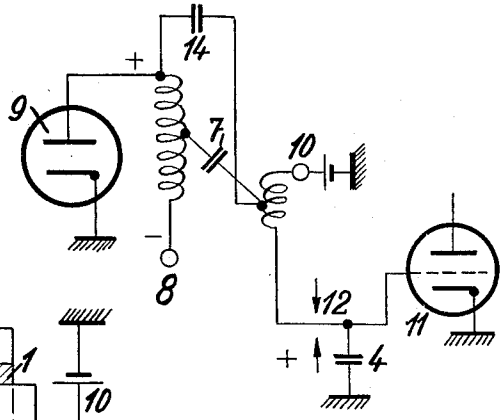


Fig. 1



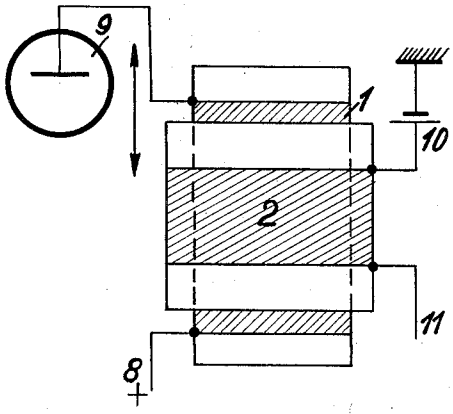


Fig. 2a

Fig. 2

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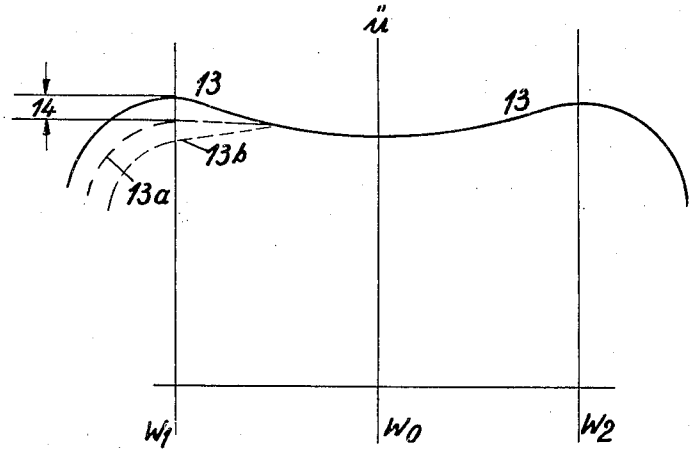


Fig. 3

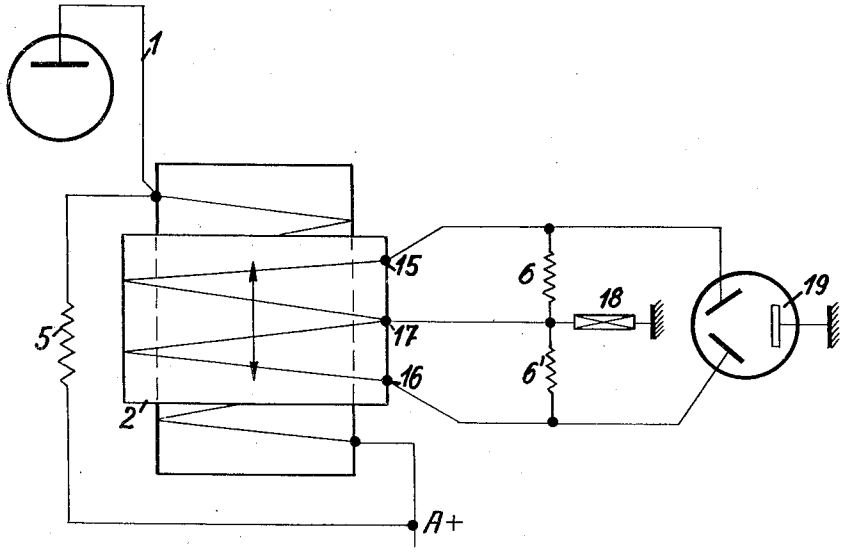


Fig. 4

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UNITED STATES PATENT OFFICE

2,152,823

COUPLING TRANSFORMER

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Application February 24, 1936, Serial No. 65,401
In Germany February 27, 1935

6 Claims. (Cl. 178—44)

The subject matter of the invention is an inductive coupling in television amplifiers which operate with carrier frequency amplification. In this connection there arises the problem of transmitting from one tube to the next one in even fashion, possibly with a slight lifting of the extreme side band frequencies, a frequency band of the width of the double image point frequency, the middle frequency of which is represented by the unmodulated carrier wave. Although the carrier-frequency method effects a decrease in the relative width of the frequency band as the carrier frequency increases, there still remains in respect of the amplifier transformer a difficult technical problem in even transmission of the double side-band width. This is particularly the case in connection with long carrier waves, as shown by the following table, in which the first column designates the carrier wave, the second the highest frequency to be transmitted, the third the carrier frequency and the last the ratio of the frequency band to be transmitted to the carrier frequency:

$\lambda T(m)$	γ_{max}	f_T	$\frac{2.\gamma_{max}}{f_T}$
	Kilocycles		*Percent*
30	600	10^7	12
150 m.	600	2.10^6	60

In two earlier applications Ser. No. 749,511 and Ser. No. 24,901/35 the applicant has already described means for controlling in the case of resonance transformers the requisite width of band. Two types of transformers are involved. The earlier application Ser. No. 749,511 describes the de-tuned transformer, the one pair of coils of which are tuned to a higher and the other pair of coils of which are tuned to a lower natural frequency than that occurring in practice. The amplification takes place in the saddle between the two natural frequencies. The resonances are flattened by parallel damping. The second application describes a fundamentally different transformer, in which primary circuit and secondary circuit are tuned to the same natural frequency, and whereby, by a fixed coupling of the two circuits, there occurs a separation of the previously unitary resonance into two coupling resonances. The present application describes an additional development of this latter system.

In the drawings

Fig. 1 shows two valves, the output of the one valve being coupled by means of a transformer with the input of the succeeding valve.

Fig. 2 illustrates a form of embodiment of the transformer according to the present invention.

Fig. 2*a* shows another circuit diagram of the transformer.

Fig. 3 shows the transmission ratio $\ddot{u}$ of the transformer according to the invention as a function of the frequency ω.

Fig. 4 shows a particular form of embodiment of the transformer adapted for push-pull operation.

According to Fig. 1, the natural frequency of the primary coil **1** and also of the secondary coil **2** is adjusted merely by effecting winding with a certain number of turns in conjunction with the natural capacities **3** and **4** of the connection. A special trimmer capacity is, in accordance with the invention, purposely avoided. In this way there is obtained the ratio of

$$\frac{L}{C}$$

which is the most favourable conceivable in individual cases, and for obtaining a prescribed decrement the comparatively smallest possible auxiliary ohmic damping is required. According to the invention, the natural frequency of the circuit **3**, **1** is made equal to the natural frequency of the circuit **2**, **4** if the two coils are very loosely coupled. Both natural frequencies are made equal to the unmodulated carrier wave in respect of which the amplifier is intended to operate. After this tuning of the single circuits has been completed the circuits are so tightly coupled with each other (coupling factor k) that there occurs the known separation of the natural frequencies into two coupling frequencies. On the basis of the known equation for these coupling waves

$$\lambda_{1,2}=\lambda_0.\sqrt{1\pm K} \tag{1}$$

it is possible by strengthening the coupling to space the two coupling waves, in accordance with the invention, to a greater extent apart than is required by the side-band width employed in practice. In accordance, therefore, with the invention operations in this case are also performed in the saddle of the frequency curve disposed between the two coupling maxima. In this saddle the transformer is equivalent to a resistance coupling, in which the effective working resistance has the following size:

$$R\ \text{eff}=\frac{L_1}{M}.\frac{1}{\omega_0 C_z} \tag{2}$$

In this L_1 is the inductance of the primary coil 1, M the adjusted mutual-inductance, C_g the grid-earth capacity of the succeeding amplifier tube, designated 4 in Fig. 1, and ω_0 the carrier frequency. The equation discloses clearly the technical advantage of the elimination in accordance with the invention of special tuning condensers and the reduction of the parallel capacities to the structurally available minimum.

According to the invention, there are provided in parallel with the primary and secondary circuits damping resistances 5 or 6 of such size that the increase of the coupling resonances as compared with the transmission value represented by the Equation 2 disappears. In special cases a small resonance increase if approximately 10–20% may be desirable, as by raising the maximum modulation frequencies it may be utilized for compensating lack of sharpness occurring at other points of the apparatus. In this case the damping resistances 5 and 6 are made somewhat larger.

The transformer according to Fig. 1 is employed with particular advantage in conjunction with screen grid tubes, as in the case of the latter the considerable increase of the capacities 3 and 4 occurring by reason of the grid-anode capacity in conjunction with the amplifying operation is missing. Taking as a basis tubes of this kind, the Equation 2 results in operating resistance of approximately 4,000 ohms for the equivalent resistance coupling. Since in the two coupling resonance points the apparent transformer resistance may be assumed to be very much higher, there result in respect of 5 and 6 values of the same order of magnitude as the value derived from the Equation 2. In actual practice, for example, the following dimensions were found:

Carrier frequency 2000 kc. (λ=150 metres),
Image point frequency 540 k. c.,
Capacity attainable c_2: 20 cm.,
Natural wave of both coil circuits, 180 metres,
Coupling factor k=approx. 50%,
Damping on the grid side 6:5,000 ohms,
Damping on the anode side 5:5,000 ohms.

Upon the assembly of a transformer of this kind particular coupling effects of a peculiar kind take place by reason of the existence of the mutual capacity of the windings. It has become possible to utilise in practice this effect, which is designated "influence coupling", in the following manner: According to Fig. 2, a coupling transformer of the kind described in Fig. 1 is produced in reproducible form by fitting two cylindrical coils one within the other. Owing to the fact that the position of the outer secondary coil over the inner primary coil is made variable the coupling factor and accordingly the width of band may be adjusted in practice and trimmed to the frequency band corresponding with the number of lines to be transmitted. According to the Equation 2 a decrease in the counter-inductance M, and accordingly a decrease in the number of image points, results in an increase in the effective coupling resistance, i. e., in an improved total amplification. In this way it is readily possible to furnish receivers with different widths of band with in each case the optimum total amplification. The stated influence coupling occurs according to Fig. 2*a* through the medium of the winding capacity 7. The resulting frequency curve which is caused by the superimposing of the intended inductive coupling with the additional capacitative influence coupling 7 is wholly different dependent on the fact as to whether the two couplings operate in opposition to each other or together.

The applicant has found that in the case of coils wound in the same direction, so-called congruent coils, a much better transmission curve is obtained if the current flowing from the battery pole 8 of the anode battery to the tube anode 9 traverses the primary coil in an upward direction, whilst the current flowing from the battery pole 10 of the grid battery to the control grid 11 of the next tube traverses the secondary coil in the opposite direction, i. e., in this case in the downward direction. This effect when employing the aid of the part-inductance 12 in Fig. 2*a* may be shown as a series resonance between 12 and 4, taking into consideration that the coupling by means of the influence condenser 7 in the example quoted according to the invention takes places with the proper polarity. The frequency curve resulting in the stated example is designated 13 in Fig. 3. The same shows the transmission ratio ü traced against the frequency ω_0 is the unmodulated carrier wave, ω_1 the higher side band frequency augmented by the image point frequency, and ω_2 the lower side band frequency. Upon reversal of the polarity of the secondary coil the portion 14, which was added to the normal curve 13*a*, is subtracted and results in the curve 13*b*, which reveals an undesirably strong drop at the short-wave end.

The stated curves were obtained with a radii ratio of 5:6 and a height of the winding amounting to approximately 15–20 cm. In other forms of construction of the transformer this auxiliary coupling 7 may be smaller. According to the invention, the most favourable effect of the frequency lifting according to Fig. 3 may be obtained in practice by the provision of a special coupling condenser 14 as shown in Fig. 2*a*. This may also be employed with advantage in those cases in which the mutual capacity has been eliminated entirely by a special screening means between the coils.

A particular form of embodiment according to the same system of equally tuned coil circuits, but adapted for push-pull operation, is shown in Fig. 4. The feature according to the invention resides in this case, in addition to the equal wave tuning and fixed coupling, in the first place in a considerable difference in diameter between the primary coil and secondary coil: ratio of the radii$\geqq$1.5, and in a large axial expanse of the secondary coil 2 in relation to the primary coil 1, so that the length of the two coils is as far as possible the same. In this way, as already shown in an earlier application Ser. No. 747,011, it may be accomplished that upon displacement of the outer coil over the inner coil in an axial direction the potentials occurring at the winding ends 15 and 16 of the unloaded coil take place exactly in phase opposition and in equal amount as compared with the middle point of the winding 17. By reason of the stated ratio of the radii set forth according to the invention the effect of the influence coupling is reduced to a considerable extent in this push-pull transformer. A primary damping 5 is applied in the case of a normal transformer according to Fig. 1 in parallel with the primary coil. The secondary damping is preferably divided at the middle (6, 6'), and the middle of the damping connected with the middle of the winding 17. In this way there is obtained an additional balancing of the counter-cadence po-

tentials. A consuming apparatus, for example the grid path of an amplifying tube, is represented by the operator 18 in Fig. 4. The number of turns which require to be provided for the secondary coil 2 of a transformer of this kind amount to more than twice the number as compared with a normal transformer according to Fig. 1 since, as well known, the capacities against earth of a connected electronic tube 19 are, in the case of a push-pull connection, in series.

I claim:

1. A high frequency transformer for carrier-frequency amplifiers, more particularly for television purposes, having a primary winding and a secondary winding, both of said windings are tuned to the same natural frequency, said tuning being effected solely by the winding inductance and the inherent capacities, said primary winding and said secondary winding being tightly coupled, the degree of said tight coupling being made variable for the purpose to vary the width of said frequency band, said transformer windings being damped by parallel resistances so that the curve defining the transmission degree over the whole frequency band is not increased at the resonance-frequencies but has nearly the same amplitude over said whole frequency band.

2. A high frequency transformer for carrier-frequency amplifiers, more particularly for television purposes, having a primary winding and a secondary winding, both of said windings are tuned to the same natural frequency, said tuning being effected solely by the winding inductance and the inherent capacities, said primary winding and said secondary winding being tightly coupled, the degree of said tight coupling being made variable for the purpose to vary the width of said frequency band, and a condenser for coupling said transformer windings additionally by a capacitative coupling said windings being poled in such manner that the two couplings superpose each other in the short-wave range, said coupling capacity being connected in such fashion with a tapping of the secondary coil that series resonance takes place in the short-wave range of the frequency curve.

3. A high frequency transformer for carrier-frequency amplifiers, more particularly for television purposes, having a primary winding and a secondary winding, both of said windings are tuned to the same natural frequency, said tuning being effected solely by the winding inductance and the inherent capacities, said primary and said secondary winding being tightly coupled, the degree of said tight coupling being made variable for the purpose to vary the width of said frequency band, said transformer windings being coupled in addition to the inductive coupling by a capacitative coupling, said capacitative coupling being represented by the natural capacity of said windings with respect to each other, said windings being poled in such manner that the two couplings superpose each other.

4. A high frequency transformer for carrier-frequency amplifiers, more particularly for television purposes, having a primary winding and a secondary winding, both of said windings are tuned to the same natural frequency said tuning being effected solely by the winding inductance and the inherent capacities, said primary winding and said secondary winding being tightly coupled, the degree of said tight coupling being made variable for the purpose to vary the width of said frequency band, said secondary being connected in push-pull fashion and earthed by means of a resistance in its middle and having damping resistances connected in parallel between its middle-tap and the opposite ends, the axial length of the said secondary being at least equal to the axial length of said primary winding, said windings being axially shiftable with respect to each other, the ratio of the diameter of said primary to that of said secondary being at least 1,5.

5. A high frequency transformer for carrier-frequency amplifiers, more particularly for television purposes, having a primary winding and a secondary winding, both of said windings are tuned to the same natural frequency, said tuning being effected solely by the winding inductance and the inherent capacities, said primary winding and said secondary winding being tightlycoupled, the degree of said tight coupling being made variable for the purpose to vary the width of said frequency, and a condenser for coupling said transformer windings additionally by a capacitative coupling, said windings being poled in such manner that the two couplings superpose each other in the short-wave range, said coupling capacity being connected in such fashion with a tapping of the secondary coil that series resonance takes place in the short-wave range of the frequency curve, said windings being wound both in the same direction, the secondary being connected to the bias potential source and earth respectively with that terminal lying at that side which is at the primary conneced to the anode whilst the opposite terminal of the secondary is connected to the grid of the associated stage.

6. A high frequency transformer for carrier-frequency amplifiers, more particularly for television purposes, having a primary winding and a secondary winding, both of said windings are tuned to the same natural frequency, said tuning being effected solely by the winding inductance and the inherent capacities, said primary and said secondary winding being tightly coupled, the degree of said tight coupling being made variable for the purpose to vary the width of said frequency band, said transformer windings being coupled in addition to the inductive coupling by a capacitative coupling, said capacitative coupling being represented by the natural capacity of said windings with respect to each other, said windings being poled in such manner that the two couplings superpose each other, said windings being wound both in the same direction, the secondary being connected to the bias potential source and earth respectively with that terminal lying at that side which is at the primary connected to the anode whilst the opposite terminal of the secondary is connected to the grid of the associated stage.

KURT SCHLESINGER.