Oct. 22, 1935. J. S. LOW 2,018,140

BAND PASS NETWORK

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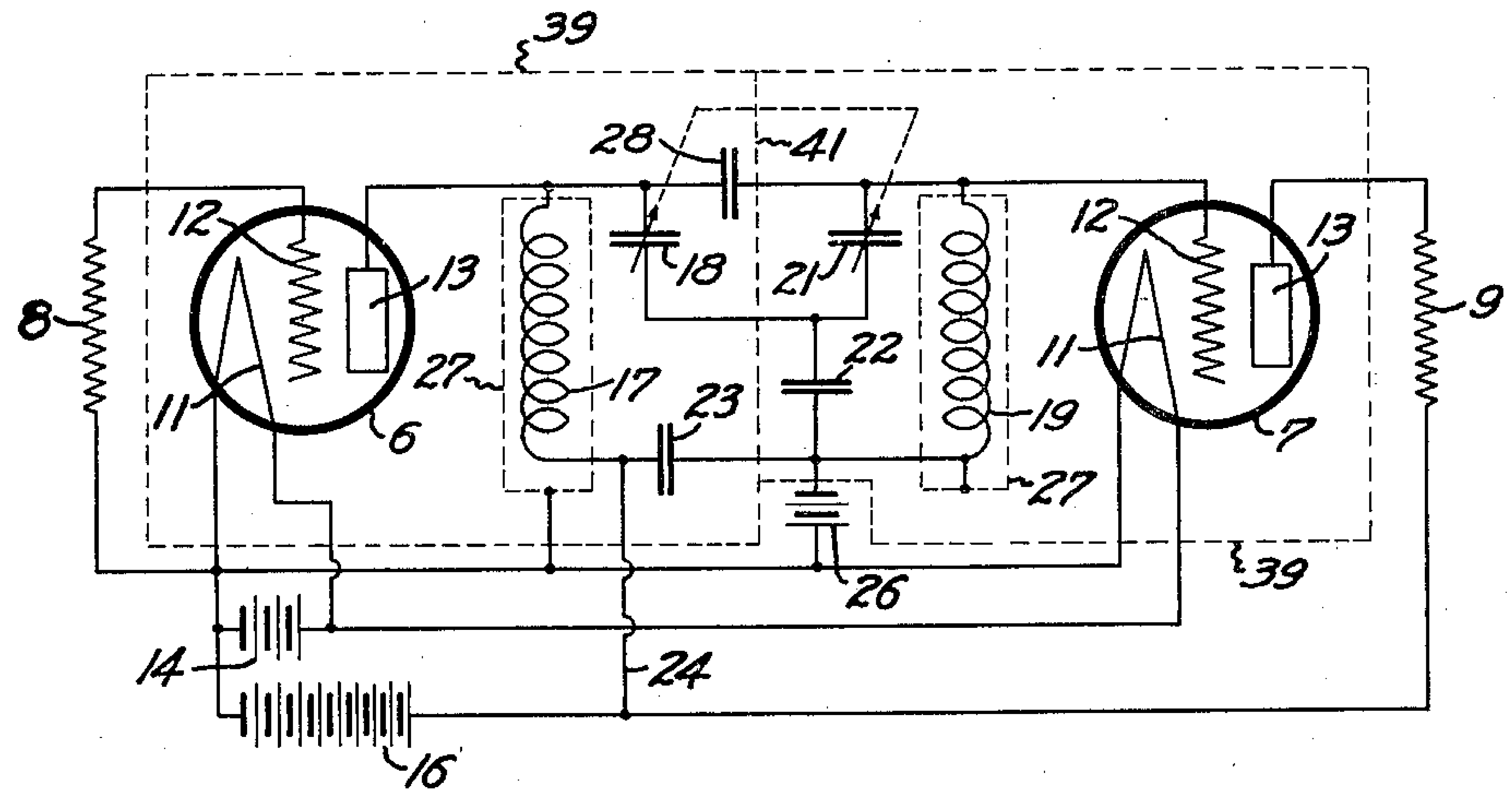
Fig. 1



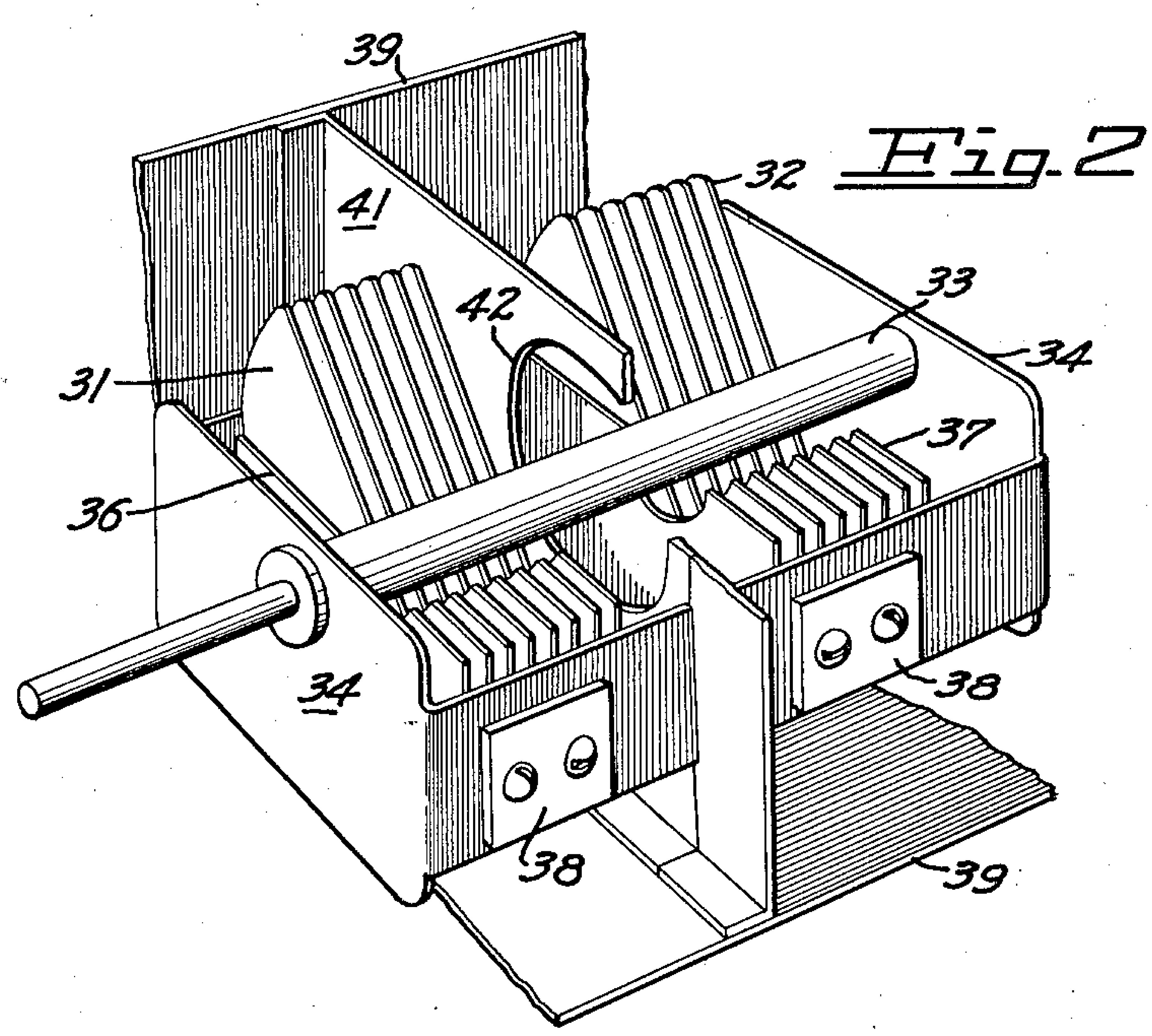


Fig. 2

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BAND PASS NETWORK

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15 Claims. (Cl. 178—44)

My invention relates to selective networks, and particularly to networks such as are used in radio receiving apparatus. Its broad purpose is to provide a network which may be tuned over a range of frequencies, and which will pass a limited and substantially constant width frequency band, on each side of the frequency to which it is tuned, over its entire tuning range.

An object of my invention is to provide a means of accurately adjusting the width of the pass band of a tuned network.

Another object of my invention is to provide a tunable band pass network which is not dependent upon magnetic coupling, and in which the inductance coils may be completely shielded.

Still another object of my invention is to provide a selfcontained tuning and coupling unit for use with such a band pass network.

A further object of my invention is to provide a band pass network which may be used either as a purely selective unit, or which may be used as a coupling unit between the stages of an amplifier.

My invention possesses other objects and valuable features, some of which will be set forth in the following description of my invention which is illustrated in the drawing forming part of the specification. It is to be understood that I do not limit myself to the showing made by the said description and drawing, as I may adopt varying forms of my invention within the scope of the claims.

Referring to the drawing:

Figure 1 is a circuit diagram of the network of my invention as used for coupling two tubes of a radio frequency amplifier.

Figure 2 is a perspective view of a condenser adapted for use as a combined tuning and coupling device in the network of my invention.

In broadly descriptive terms the network of my invention comprises a pair of tuned circuits having a common reactor, and a bridging reactor of similar phase characteristics to the common reactor connecting the circuits at a point remote from the common reactor. In its preferred form capacity reactors are used as the common and bridging reactors, and the bridging reactor may be made as a part of the tuning condenser unit used with the circuit.

In more detailed terms, Fig. 1 is a diagram of the network used as an intertube coupler in a radio frequency amplifier. In order to simplify the drawing but two tubes 6 and 7 of such an amplifier are shown, the input circuit to the tube 6 being represented by an impedance 8, and the output circuit by an impedance 9. These circuits may be networks similar to that to be described in detail, or they may be conventional or special circuits of other types.

The vacuum tubes shown are conventional triodes having filaments 11, control electrodes or grids 12, and anodes or plates 13. The triodes shown are the familiar battery type tubes, whose filaments are supplied by an A battery 14 and whose plate circuits are supplied by a B battery 16, but it is obvious that alternating current tubes may be substituted or that tetrodes may be used in place of the triodes, without affecting the performance of the band pass network which connects them.

Connected to the plate of the tube 6 is a tuned resonant circuit comprising an inductor 17 and a variable condenser 18. A similar tuned circuit comprising an inductance 19 and a variable condenser 21 is connected to the grid of the tube 7. One of the sets of elements of the condensers 18 and 21 are connected together, and to the junction of these condensers is connected a common fixed condenser 22, the other side of which connects to the low potential end of the two inductors 17 and 19. The connection between the condenser 22 and the inductor 19 is direct; that between the inductor 17 and the condenser 22 is thru a blocking condenser 23 which is of a sufficiently large value to have no appreciable effect on the tuning of the resonant circuit, that is, it is of one to two orders of magnitude larger than the condenser 22.

A lead 24 connects from the battery 16 to the low potential end of the inductor 17 and thence to the plate of the tube 6. The low potential end of the inductor 19 connects to the filament circuit of the tube, preferably thru a biasing battery 26. The inductors 17 and 19 are preferably completely enclosed in shields 27.

A bridging condenser 28 connects the high potential end of the coils 17 and 19. This condenser is of very small capacity as compared to the condensers 18. The condenser 22 is of very large capacity as compared to the condenser 18. The method of selecting these capacities will next be considered.

The coupling network consists of two resonant circuits which are very loosely coupled. It is well known that the resonance curve of such a pair of coupled circuits differs materially from that of either circuit considered by itself. Assuming that the two circuits are substantially identical and tuned to the same frequency, there is a certain value of coupling, known as critical coupling, where the top of the curve is substantially flat and the sides are very steep. That is, there is a band of frequencies to which the circuit responds at substantialy uniform intensity, while frequencies without this band are rejected. Less than critical coupling weakens the response, and gives slightly convex top to the response curve, while more than critical coupling also lessens the response but results in a concave top curve, that is, in a curve having two "humps" or maxima.

If f is the frequency to which the circuits considered individually are in resonance, the frequencies of maximum response of the circuit will be very nearly

$$f'=f\sqrt{1+k}$$

and

$$f''=f\sqrt{1-k},$$

where k is the coefficient of coupling.

Experience has shown that for radio telephone reproduction it is desirable to have the circuit respond substantially uniformally over a band of about 10 kilocycles, i. e. a band 5,000 cycles on either side of the frequency f of the carrier wave. Experience has further shown that if f' and f'' are about 5,000 cycles apart or half the width of the band, this result is very closely approximated. Owing to the variation of resistance in radio frequency circuits with frequency, and the corresponding change in shape of the resonance curve, it is desirable that f' and f'' be slightly farther apart on the lower frequencies and slightly closer on the higher, but the rule given is sufficiently accurate for a first approximation.

Where k is small the difference $f'-f''$ is very nearly $f\times k$. It is therefore evident that if k is a constant, the band passed by such a network varies almost directly as f. Considered in terms of the present radio broadcasting frequency spectrum, from 550 kilocycles to 1500 kilocycles, the width of the pass band will be approximately three times as great at the high frequency end of the band as at the low frequency end. In order to pass a band of constant width, k must be made to vary substantially inversely as the frequency.

In the network here described k comprises the sum of two components, the first being due to the coupling introduced by the condenser **22** which may be termed k_1, while the other is due to the condenser **28** and may be termed k_2. Calling the capacity of condenser **22** C_1 the capacity of condenser **28** C_2, and the capacity of condensers **18** and **21** C,

$$k_1=\frac{C}{C+C_1},$$

and

$$k_2=\frac{C_2}{C+C_2}$$

As C is the tuning condenser, its capacity varies with the frequency to which the network is tuned, and if the inductances **17** and **19** are each equal to L,

$$C=\frac{1}{(2\pi f)^2L}.$$

Substituting in the equations for k_1 and k_2,

$$k_1=\frac{1}{1+(2\pi f)^2LC_1},\ k_2=\frac{C_2(2\pi f)^2L}{1+C_2(2\pi f)^2L}$$

Since both k_1 and k_2 are very small, the expressions

$$k_1=\frac{1}{(2\pi f)^2LC_1},$$

and $k_2=(2\pi f)^2LC_2$ are sufficiently accurate for the purposes of computation.

If, as is desirable in networks of this character, the ratio of inductance to resistance in the coils is high, a desirable pass band is obtained by making $f'-f''=6{,}000$ cycles at $f=550$ kilocycles, and $f'-f''=4{,}000$ cycles at $f=1{,}500$ kilocycles. Hence, taking $f'-f''=kf=(k_1+k_2)f$, suitable values for k are .0109 at 550 kc., and $k=.0027$ at 1500 kc.

We may now put

$k_1+k_2=k$ at the two extreme frequencies in the band, and substituting in the above equations for k_1 and k_2, and taking 200 microhenries as a suitable value for L, we obtain the simultaneous equations

$$(2\pi\times550\times10^3)^2\times200\times10^{-6}C_2+\frac{1}{(2\pi\times550\times10^3)^2\times200\times10^{-6}C_1}=.0109$$

$$(2\pi\times1500\times10^3)^2\times200\times10^{-6}C_2-\frac{1}{(2\pi\times1500\times10^3)^2\times200\times10^{-6}C_1}=.0027$$

solving for C_1 and C_2 we obtain

$$C_1=3.90\times10^{-8}\text{ farads}=.039\text{ mf.}$$

$$C_2=.07\times10^{-12}\text{ farads}=.07\text{ m. m. f.}$$

It will be realized that while the former capacity is relatively large as radio capacitances go, the capacitance C_2 is so small as to be with difficulty obtainable. The method of securing an accurate capacitance of this value which I prefer, is to make the tuning unit of the well known "gang condenser" type as shown in Figure 2, in which the two rotor members **31** and **32** are electrically connected to a common shaft **33** which is grounded to the condenser frame **34**. The stator members **36** and **37** are insulated from the frame and supported by the strips **38** in the usual manner.

Complete shielding, indicated in Figure 1 by the dotted lines **39**, surrounds the individual tuned circuits. The shield **41** between the two stator sections, forms a part of the general shielding, and this shield is cut away as shown at **42** to provide a capacitance of the proper magnitude between the stator members. The area of the opening in the shield depends, of course, both upon the magnitude necessary for the coupling capacity C_2 and upon the spacing of the stators, the latter being determined by mechanical considerations.

I am aware that it has been proposed to construct constant width tuned band pass networks by a combination of capacity and inductive coupling. This system, however, inevitably introduces accidental capacity couplings between the inductors which practically vitiate its usefulness. The method of my invention, however, enables the designer to reduce the inductive couplings to substantially nil, leaving only the precalculated capacity couplings to affect the circuits.

The figures given in the above example are to be considered as illustrative only, and have not been determined with greater than slide rule accuracy. Second order infinitesimals have, moreover, been persistently neglected both in the derivation of the formulas and in the computations. The results, however, are sufficiently accurate for all ordinary purposes, and exact results may be obtained by methods which are published in many texts and are familiar to those skilled in the art.

I claim:

1. A band-pass network comprising a pair of tuned circuits having a common capacitor therein and a bridging capacitor between said circuits, said capacitors being proportioned to provide a substantially constant width of pass band as said circuits are tuned syntonously over a range of frequencies.

2. A band pass network comprising a pair of similar tuned circuits having a common capacitor therein, and a bridging capacitor between said circuits, said capacitors being proportioned to provide a substantially constant width of pass band with variable tuning of said circuits.

3. A band pass network comprising a pair of tuned circuits each comprising a fixed inductor and a variable capacitor, a capacitor common to said circuits and having each of said inductors and capacitors connected thereto, and a bridging capacitor connecting the junctions of said inductors and variable capacitors remote from their connections to said fixed capacitor.

4. A tuned band pass network comprising a pair of resonant circuits having fixed inductors with substantially zero mutual inductance and variable capacitors, a capacitor common to said circuits, and a bridging capacitor connecting said circuits at a point remote from said common capacitor.

5. A tuned band pass network comprising a pair of resonant circuits having fixed inductors with substantially zero mutual inducance and variable capacitors having a mutual capacitance between the elements thereof, and a capacitance common to said circuits.

6. A band selective transmission network comprising a par of syntonous tuned circuits, each comprising an inductance and a variable tuning capacity, means for varying the tuning of said circuits simultaneously, coupling means comprising a capacity common to both of said circuits and additional coupling capacity connecting said tuned circuits serially, said common capacity being large compared with the tuning capacities of said tuned circuits and said series capacity being small relatively thereto.

7. A band-pass network comprising a pair of tuned circuits each comprising a fixed inductor and a variable capacitor, means for varying the tuning of said circuits simultaneously, a capacitor common to said circuits and having one terminal of each of said variable capacitors connected to one terminal thereof, additional coupling capacity between the other terminals of said variable capacitors, said additional capacity being constituted by direct capacitance between said variable capacitors and partial shielding means between said variable capacitors adapted to limit the direct capacitance to a value which in cooperation with the common capacitance will maintain a substantially constant width transmission band throughout the tuning range of the network.

8. A band-pass network comprising a pair of tuned circuits each comprising a fixed inductor and a variable capacitor, means for varying the tuning of said circuits simultaneously, a capacitor common to said circuits providing low impedance coupling therebetween, and additional coupling capacity between the terminals of said variable capacitors remote from said common capacitor, said additional capacity being provided by direct capacitance between said variable capacitors and being proportioned to cooperate with said common capacity to maintain the pass-band substantially constant in width throughout the tuning range of the network.

9. The combination with two serially connected inductances having substantially zero electromagnetic coupling, of a capacitive coupling between the non-common ends of said inductances, a condenser having one terminal connected to the junction of said inductances, a pair of tuning condensers having a common terminal connected to the other terminal of said first condenser, the opposite terminals of said tuning condensers being connected to the respective non-common terminals of said inductances, and mechanical means connecting the adjustable elements of said tuning condensers to insure their simultaneous adjustment, the tuning condensers and inductances having such values that the two tuned circuits remain continuously in resonance throughout the range of adjustment of said tuning condensers.

10. A high frequency network comprising a pair of resonant oscillation circuits having fixed inductors with substantially zero mutual inductance between them, variable tuning condensers connected to said inductors having a mutual capacitance between stator elements thereof, said capacitance providing electrostatic coupling between said circuits, and a single means for simultaneously adjusting said tuning condensers.

11. A high frequency network comprising a pair of resonant oscillation circuits having fixed inductors, means for shielding said inductors whereby there exists substantially zero mutual inductance between them, variable tuning condensers connected to said inductors having a mutual capacitance between stator elements thereof, said capacitance providing electrostatic coupling between said circuits, and a single means for simultaneously adjusting said tuning condensers.

12. In combination, in a high frequency transmission system, a source of high frequency energy, a tunable oscillation circuit coupled thereto, a high frequency space discharge amplifier, a second tunable oscillation circuit between said first circuit and said amplifier input circuit, and compound coupling means between said first and second tunable circuits consisting of a capacitor common to said tunable circuits and a bridging capacitor between said tunable circuits, said capacitors being so proportioned as to provide a substantially constant width of pass band with variable tuning of said circuits.

13. In combination, in a high frequency transmission system, a source of high frequency energy, a tunable oscillation circuit coupled thereto, a high frequency space discharge amplifier, a second tunable oscillation circuit between said first circuit and said amplifier input circuit, compound coupling means between said first and second tunable circuits consisting of a capacitor common to said tunable circuits and a bridging capacitor between said tunable circuits, said capacitors being so proportioned as to provide a substantially constant width of pass band with variable tuning of said circuits, and means for simultaneously and similarly tuning said oscillation circuits to a desired frequency.

14. A receiver comprising a pair of adjacent

radio frequency amplifying stages, each stage being provided with a tuned circuit including capacitive tuning means, said capacitive tuning means of both stages being so constructed and arranged as to provide capacitive coupling between the respective tuned circuits of said adjacent stages, and a capacitor common to said tuned circuits, said capacitive coupling and said common capacitor being so proportioned as to provide a substantially constant width of pass band with syntonous tuning of the circuits.

15. In a receiver, a stage of radio frequency amplification, a subsequent radio stage, a tunable circuit associated with each of said stages, tuning means in each of said circuits for tuning the latter to any desired frequency in a predetermined range of frequencies, said tuning means comprising a pair of adjacent variable condensers each having a plurality of stator and rotor plates, the rotor plates being mounted on a common control shaft, coupling between the said stages being provided by the capacity between adjacent stator plates of the adjacent condensers, and additional coupling between the said stages being provided by a capacitor common to both of said tunable circuits, whereby a substantially constant band width is maintained with syntonous tuning of the circuits.

JOHN S. LOW.