Oct. 7, 1941. W. VAN B. ROBERTS 2,258,147

COUPLING CIRCUIT

Filed Jan. 28, 1939

Fig. 1

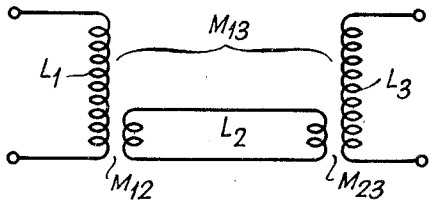


Fig. 2

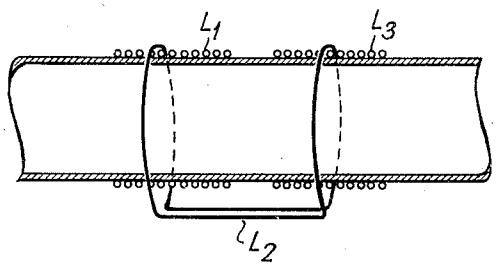
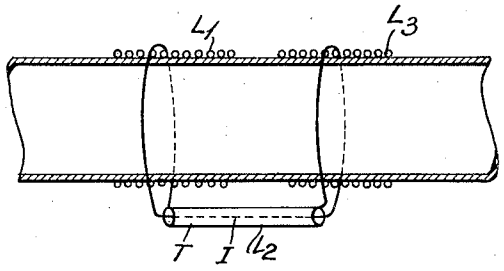


Fig. 3



INVENTOR
WALTER VAN B. ROBERTS
BY H. S. Sawyer
ATTORNEY

Patented Oct. 7, 1941 2,258,147

UNITED STATES PATENT OFFICE

2,258,147

COUPLING CIRCUIT

Walter van B. Roberts, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware.

Application January 28, 1939, Serial No. 253,336

3 Claims. (Cl. 178—44)

An object of this invention is to provide a means for obtaining increased effective mutual inductance between a pair of coils.

A further object of this invention is to provide a means for varying the effective mutual inductance between a pair of coils without the necessity for employing flexible conductors or sliding contacts.

Additional objects are to provide a means for bucking out undesired mutual inductance between a pair of coils and to provide a novel method of design for a link circuit of minimum self inductance.

The occasion sometimes arises, especially in radio transmission circuits, for desiring a large mutual inductance between two coils whose dimensions and shapes are such that large mutual inductance cannot be obtained by suitable positioning or where undesirable capacity coupling effects occur when the two coils are brought sufficiently intimately together to obtain the desired mutual inductance.

The present invention provides for the combination of as much direct mutual inductance as feasible with a link circuit so arranged as to greatly increase the effective or equivalent mutual inductance.

In describing my invention, reference will be made to the attached drawing wherein:

Fig. 1 shows schematically a pair of coils coupled both by mutual inductance and also by a link circuit; Fig. 2 shows the physical arrangement of a typical construction employing the invention; Fig. 3 shows a preferred construction of the link circuit and its arrangement with respect to the pair of coils with which it is associated.

Referring to Fig. 1, mathematical analysis indicates that this circuit is equivalent to a pair of coils having mutual inductance

$$\frac{M_{12}M_{23}}{L_2}+M_{13}$$

This is based on the assumption that the circuital impedance of the link circuit consists chiefly of its inductive reactance. Strictly speaking, L_2 in the above expression should be replaced by the circuital impedance divided by $j\omega$. In this equation M_{13} is the direct mutual inductance of L_1 and L_3; M_{12} is the mutual inductance of L_1L_2; and M_{23} is the mutual inductance of L_2 and L_3. From the expression it will be seen that the additional effective mutual inductance provided by the link circuit may be arranged to aid or oppose the direct mutual M_{13} according to the relationship given the relative polarities of the various couplings. It will also be observed that any unnecessary inductance in the link circuit itself reduces the coupling effect of the link circuit so that for best results the link should be designed to have a minimum inductance in the portion connecting the coupling turns at the ends.

Fig. 2 represents a pair of coils L_1 and L_3 which for constructional reasons cannot readily be arranged to provide a desired mutual inductance. By the addition of a link circuit L_2 as shown, the equivalent mutual inductance is greatly increased. There is also a change in the apparent self inductance of each coil due to the link circuit, but this can usually be taken care of in the design of the circuits to be coupled and is not usually of any great consequence. If the link of Fig. 2 is moved axially along the coils, its coupling effect is varied so that such motion affords a very simple means for adjusting the effective mutual inductance between the coils. When coils of heavy conductors are used it is not ordinarily a simple matter to vary the mutual inductance as the conductors of the circuits do not bend easily to permit relative motion of the coils.

Another use for the link circuit is to buck out undesired magnetic coupling. In this case the relative polarity of one of the mutual inductances of Fig. 1 is reversed and the link is then slid along the coils until the effective mutual vanishes. In transmitter construction it is often inconvenient to mount coils non-inductively and even if this is attempted there often remains some residual coupling which cannot readily be eliminated by adjusting the coil positions if the coils are composed of heavy conductors solidly mounted.

It has been mentioned above that the link circuit becomes less effective as its inductance increases. Its inductance includes the inductance of the coupling turns at the ends, and also the inductance of the pair of conductors joining these coupling turns. As to the turns themselves, their inductance cannot be decreased very greatly as they must have a diameter sufficient to enclose the coil flux. Of course, it is obvious that the turns should not be made any larger than necessary for this purpose and that the wire should be of large size to further reduce both inductance and resistance. The number of turns used at each end of the link depends upon the particular circuit, but I have found that in most cases a single turn at each end is sufficient if the

conductors connecting the turns are made concentric as shown in Fig. 3. In this figure, conductor T may be a piece of copper tubing while conductor I is a heavy solid wire electrically connected to T as shown. Since the inductance per unit length of concentric line depends upon the ratio of the inner diameter of conductor T to the outer diameter of conductor I, it is preferable to use as thick a wire for the inner conductor as possible while still allowing space for insulation between the two conductors. The turns themselves are also preferably covered with insulation. The link circuit is, of course, bent into whatever shape may be necessary to permit the end turns fitting over or within the coils to be coupled.

Having thus described my invention, what I claim is:

1. In combination, a pair of coils having mutual inductance therebetween, a link circuit comprising a winding of at least one turn coaxial with each of said pair of coils and a concentric line of low inductance connecting said windings.

2. In combination, a pair of coils having mutual inductance therebetween, a link circuit comprising a winding of at least one turn coaxial with each of said pair of coils and a concentric line of low inductance connecting said windings, said link circuit being movable along the axes of said coils whereby the total effective mutual inductance is variable.

3. In combination, a pair of inductance coils inductively related, and means for adjusting the effective inductance between said coils comprising a winding, adjustably coupled to each coil, and concentric conductors connecting said windings together.

WALTER VAN B. ROBERTS.