Dec. 6, 1938. G. M. WRIGHT ET AL 2,139,055

HIGH FREQUENCY SYSTEM HAVING REMOTE CONTROL

Filed Jan. 11, 1936 2 Sheets-Sheet 1

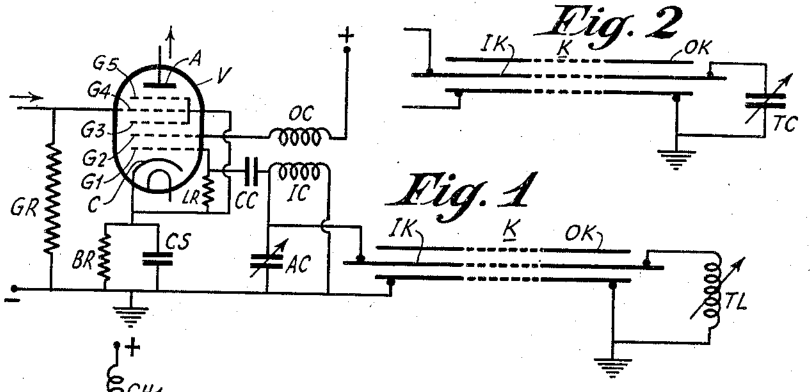


Fig. 2

Fig. 1

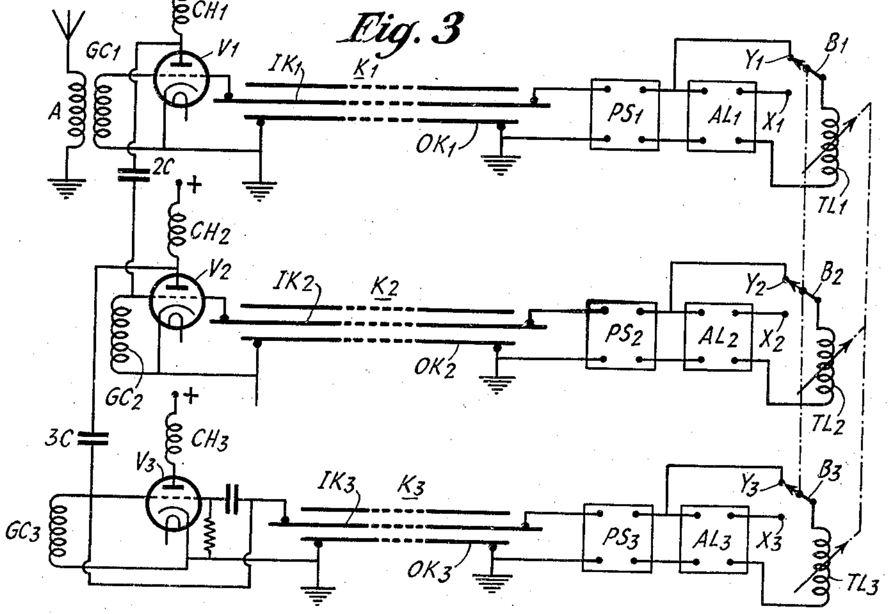


Fig. 3

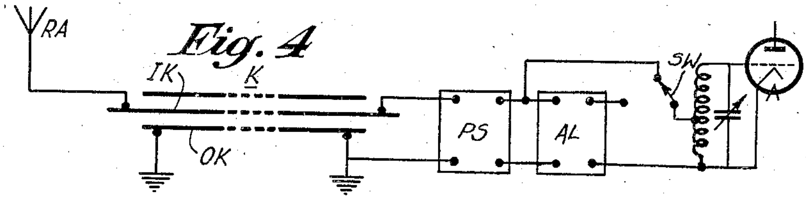


Fig. 4

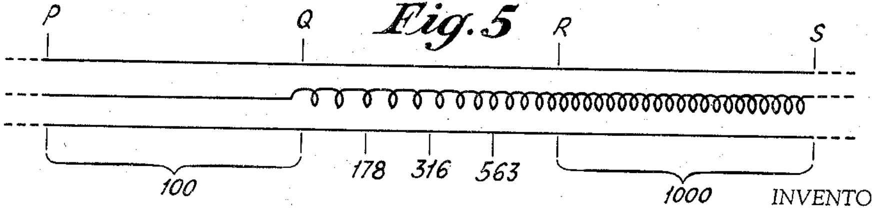


Fig. 5

INVENTOR.
GEORGE MAURICE WRIGHT
NOEL MEYER RUST

BY

HGrover
ATTORNEY.

Dec. 6, 1938. G. M. WRIGHT ET AL 2,139,055

HIGH FREQUENCY SYSTEM HAVING REMOTE CONTROL

Filed Jan. 11, 1936 2 Sheets-Sheet 2

Fig. 6

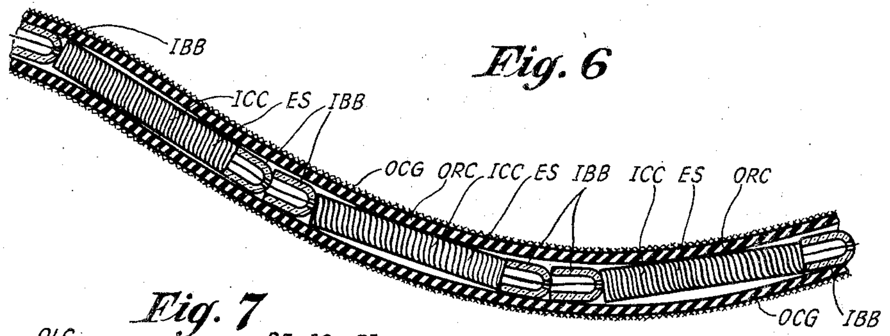


Fig. 7

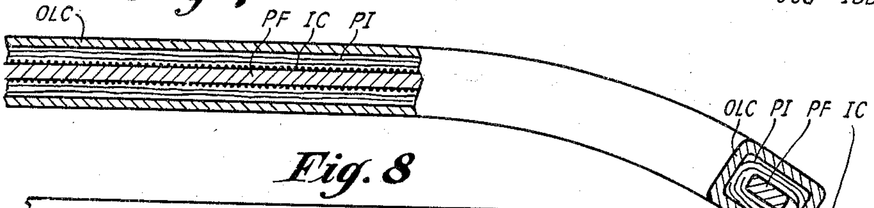


Fig. 8

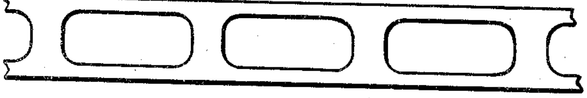


Fig. 9

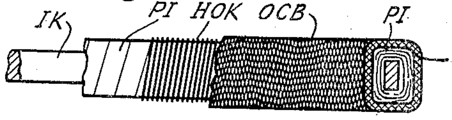


Fig. 10

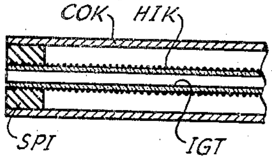


Fig. 11

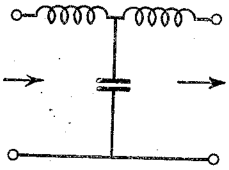


Fig. 12

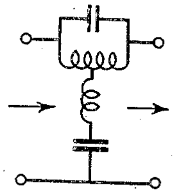
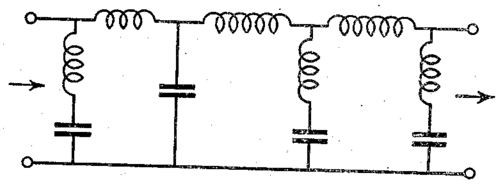


Fig. 13



INVENTOR.
GEORGE MAURICE WRIGHT
NOEL MEYER RUST

BY

ATTORNEY.

Patented Dec. 6, 1938 **2,139,055**

UNITED STATES PATENT OFFICE

2,139,055

HIGH FREQUENCY SYSTEM HAVING REMOTE CONTROL

George Maurice Wright, Bicknacre, and Noël Meyer Rust, Chelmsford, England, assignors to Radio Corporation of America, a corporation of Delaware

Application January 11, 1936, Serial No. 58,748
In Great Britain November 14, 1934

2 Claims. (Cl. 250—20)

This invention relates to remote control arrangements and feeder arrangements for use in radio and like high frequency systems, and more particularly to arrangements wherein high frequency apparatus is connected together through cables which are required to be of relatively long length.

An important application of the invention is to the remote tuning of electrical oscillation circuits, such for example as radio frequency tuned circuits in radio receivers, and in this connection the invention provides improved arrangements whereby a tuned circuit may be tuned by means of an adjustable reactance which is connected to the remainder of the said circuit through a cable which may be of relatively long length.

Another important application of the invention is to the connection of a radio receiver to a radio receiving aerial. In this application the invention enables efficient working to be obtained when a radio receiver is situated at a relatively great distance from a cooperating receiving aerial and is connected thereto through a cable.

Experiments with remote control arrangements and with arrangements wherein a receiving aerial is remotely situated from a receiver cooperating therewith, have indicated that even if the distances involved are not great, as soon as it becomes necessary to employ a length of cable of more than a few feet reflection phenomena exercise a major effect on the operation of the connecting cable. Moreover, any attempt to design a cable system to link a receiver to a remote receiving aerial using methods at present customary in the art and where the system is required to operate over a wave band such as is usual in ordinary broadcast reception, results in circuit complexities which become impracticable commercially.

Obviously where a cable is to be used in a radio or similar high frequency circuit—for example, for remote tuning control or for connecting a receiving aerial to a receiver or for like purposes—it is not sufficient to regard the cable merely as a lumped capacity at the frequencies concerned and to neglect reflection effects altogether. Hitherto it has been the most usual practice to attempt to operate such a cable under conditions where no reflection occurs; that is to say, it has been sought to terminate the cable by a resistance equal to its surge impedance and thereby avoid reflection effects. In fact, however, more particularly where variable tuning is in question, this is not practical.

In its broadest aspect the present invention consists in avoiding the difficulties which have hitherto been met with by deliberately utilizing reflection effects in the cable.

According to one feature of this invention, remote tuning control of an oscillatory circuit is effected by means of a variable reactance which is connected to the remainder of said circuit through a cable and the electrical length of a cable and the mean value of the variable reactance are so chosen that at about the middle of the tuning range the impedance of the said reactance is approximately equal to the characteristic impedance of the cable while the electrical length of the cable is approximately a quarter or a multiple of a quarter of the wave length at the said middle of the tuning range.

According to another feature of the invention the transfer of radio or like high frequency energy from one point to another—for example from a receiving aerial to the first circuit of a co-operating receiver—is effected through a high frequency cable which is of such electrical length that reflection can occur thereon, and which is so constructed that the propagation of energy therealong is at relatively slow velocity; that is to say, the cable is so constructed that its electrical length substantially exceeds its physical length.

In order that the invention may be the better understood the theoretical principles underlying it will first be briefly described.

The input impedance Z_{IN} of a cable whose series impedance per unit length is X, and whose shunt admittance per unit length is Y, and which is terminated by a load represented by a vector quantity Z_R is given by the following expression:

$$Z_{IN}=\frac{Z_0(Z_R\cosh\gamma l+Z_0\sinh\gamma l)}{(Z_0\cosh\gamma l+Z_R\sinh\gamma l)}\quad\ldots\quad(1)$$

where Z_0 is the characteristic impedance of the cable, γ is the propagation constant and l is the length of the line. γ is a vector quantity which equals $\alpha+j\beta$, where α is the attenuation constant and defines the losses, and β is the wave length constant and defines the phase change. For lines less than one wave length long α can be neglected in comparison with β and the above expression may, with reasonable accuracy, accordingly be rewritten:

$$Z_{IN} \doteq \frac{Z_0(Z_R \cos l + jZ_0 \sin l)}{(Z_0 \cos l + jZ_R \sin l)}$$

Under quarter wave conditions

$$\beta l = \frac{\pi}{2}$$

radians or 90° and

$$Z_{IN} \doteq \frac{Z_0^2}{Z_R} \text{ as } \gamma = \sqrt{XY}$$

For the quarter wave length condition

$$l \doteq \frac{1}{4FLC}$$

where F is the frequency and L and C are the inductance and capacity per unit length, respectively, and

$$Z_0 = \sqrt{\frac{L}{C}}$$

The present invention takes advantage of the fact that as Z_R appears as the denominator in the fraction

$$\frac{Z_0^2}{Z_R}$$

the process of dividing Z_0^2 by Z_R reverses the sign of the vector Z_R to obtain the quotient Z_{IN}. In practice Z_0 is always resistive for cables for use for high frequency work. If with the quarter wave condition Z_R be made an inductive load Z_{IN} will be capacitative and vice versa. This reversal of the sign of the reactance effect occurs over a range of cable wave length from ⅛th of the working wave length through ¼th of the working wave length to ⅜ths of the working wave length if the load reactance Z_R is at the same order of magnitude as Z_0. If Z_R is larger numerically than Z_0 the range of cable wave length where the reactance sign reverses at the input end is extended as regards wave lengths less than ¼th and contracted as regards wave lengths more than ¼th; that is to say, at ⅛th the working wave length and for shorter wave lengths the sign will be reversed, but on the other hand it will no longer be possible to work up to ⅜ths of the working wave length without changing the sign of the input reactance to make it the same as that of Z_R. The larger is Z_R the more the range be extended on the short wave side of the reversal point and contracted on the longer wave side of this point. If Z_R is made smaller than Z_0 an effect of the opposite sort will take place, that is to say, the range will be contracted on the shorter wave side and extended on the longer wave side of the reversal point, the degree to which the effects occur depending on the relative values of Z_R and Z_0 and increasing as Z_R is made smaller as compared with Z_0.

It will now be appreciated that by utilizing the present invention a variable inductance at one end of a cable can be made to produce the effect of a variable condenser at the other end or a variable capacity at one end can be made to produce the effect of a variable inductance at the other end, and, in practice, using approximately quarter wave length cable conditions, a 2:1 frequency range or even more can be obtained with remote reactance tuning of this sort. If a length of cable longer than the working wave length is required, the said length of cable may be made any odd plurality of quarter wave lengths long at the centre of the frequency range; it may be three quarters, five quarters, seven quarters (and so on) of the working wave length long at the centre of the tuning range. In general, however, the smallest length of cable which is permissible, having regard to other requirements, will be used in order to minimize the losses as far as possible and in order to obtain as long a tuning range as possible. It will be appreciated that as the length of the cable increases, the frequency range for which the same reactance sign is preserved is reduced, this range being less for a cable three quarters of the wave length long than for one only one quarter of the wave length long.

Reference to the formulas above given will also show that if the product βl is made equal to π, that is equal to 180°, $Z_0 = Z_R$ and the input impedance of the cable will be equal to and of the same sign as the load impedance. In other words, under half wave length conditions a variable capacity at one end of the cable will act as a variable capacity at the other end similarly a variable inductance at one end of the cable will act as a variable inductance at the other. In this case, however, the frequency range available will generally be found to be less than 2:1. As Z_R is changed in magnitude relative to Z_0 the frequency range will shift to one side or the other of the half wave length frequency in a similar manner to that caused by changes in magnitude in Z_R for the quarter wave case. It is possible to make a cable any number of half wave lengths long but the greater the number of half wave lengths the smaller is the range of control and obviously the greater will tend to be the losses.

An important but by no means limiting application of the invention is to tuning of the local oscillator of a superheterodyne receiver of the kind wherein the beat frequency is greater than the highest frequency in the range of frequencies to be received. It is well known that in a superheterodyne receiver of this kind the required frequency range to be covered by the local oscillator (expressed in terms of the ratio of the highest local oscillator frequency to be obtained to the lowest oscillator frequency to be obtained) is much less than the frequency range of the receiver as a whole expressed as the ratio of the highest frequency to be received to the lowest frequency to be received. Thus in the case of a superheterodyne receiver operating with a beat frequency of 2,000,000 cycles, a receiving range of from 150,000 to 1,500,000 cycles may be covered by using a local oscillator which may be tuned anywhere between 2,150,000 cycles and 3,500,000 cycles. Taking these figures it will be seen that a 10:1 receiving range can be covered by a local oscillator having a frequency range of only 1.63/1. Such a range of frequencies can easily be obtained with remote control through quarter or half wave length cable arrangements in accordance with this invention, and two simple arrangements suitable for use for such a purpose will now be described by the aid of the accompanying drawings, in which:

Fig. 1 is a circuit diagram in which the radio frequency signal is applied to the fourth grid of a vacuum tube;

Fig. 2 is a modification of the arrangement of Fig. 1 wherein the far end of the high frequency cable has a variable capacity connected thereto;

Fig. 3 is a circuit diagram of a multi-stage tunable multi-range receiver;

Fig. 4 is a circuit diagram of an antenna coupled to a tuned circuit of a receiver;

Fig. 5 is a diagram of a cable having an inductance connected therewith;

Fig. 6 is a sectional detail of a low velocity cable;

Fig. 7 is a detail partly in section of a low velocity cable;

Fig. 8 is a detail of a ladder-like arrangement for a low velocity cable;

Fig. 9 is a detail partly in section of a helical wound cable;

Fig. 10 is a detail partly in section of a low velocity cable wound upon a glass tube;

Fig. 11 is a diagram of a low pass filter;

Fig. 12 is a diagram of a T-type filter; while

Fig. 13 is a diagram of a composite type filter.

In the first of these arrangements, which is illustrated in Fig. 1 of the accompanying drawings, received radio frequency signals are applied to the fourth grid G_4 (counting from the cathode) of a so-called "pentagrid" tube V, that is to say, a tube having five grids G_1 G_2 G_3 G_4 G_5 in succession between cathode C and anode A which tube operates as a combined first detector and local oscillator. The said fourth grid G_4 is connected to earth through a suitable grid resistance GR and the cathode is also connected to earth through the usual capacity shunted bias resistance combination CS, BR. The third and fifth grids G_3 and G_5 are connected together as in the usual way for so-called pentagrid oscillator converters and the second grid G_2, which acts as an oscillator anode, is connected to a source (not shown) of positive potential through a coil OC which is coupled to another coil IC which is earthed at one end, its other end being connected through a suitable condenser CC to the first grid G_1 of the pentagrid tube V. Although in Figure 1 a so-called "pentagrid" type of mixer arrangement is shown it is to be clearly understood that, as regards the mixing arrangement, this is purely illustrative and that other well-known mixer arrangements—e. g., an arrangement employing a so-called triode-hexode tube—may be used. The coil IC forms part of the frequency determining circuit of the local oscillator portion of the pentagrid tube and is shunted by a small adjustable condenser AC or so-called "trimmer" condenser. The first grid G_1 is connected to the cathode C of the pentagrid tube V through a grid resistance LR and the resultant beat frequency is taken off in the usual way from the anode circuit to the customary beat frequency amplifier (not shown). Remote tuning of the frequency determining circuit of the local oscillator portion of the pentagrid tube is obtained by means of a variable inductance TL which is situated at the far end of a high frequency cable K. The unearthed side of the "trimmer" condenser AC is connected to one end of the central conductor IK of the high frequency cable and one side of the variable tuning inductance TL is connected to the other end of this central conductor. The outer conductor OK of the high frequency cable—which conductor may be the usual external screen—is earthed and also connected to the remaining terminal of the variable tuning inductance TL. The electrical length of the cable is so chosen that at approximately the middle of the desired tuning range of the local oscillator it is one quarter of the wave length long and at this middle frequency the impedance of the tuning inductance is approximately equal to the characteristic impedance of the cable. With this arrangement the remotely situated variable inductance TL will act as though it were a variable capacity directly in shunt with the trimmer condenser AC.

The above-described arrangement may be modified as shown in the accompanying Figure 2 by using instead of a remote variable inductance TL a remote variable capacity TC. This remote variable capacity TC will act as though it were a variable inductance forming part of the frequency determining circuit of the local oscillator and of course, where a remote variable capacity is used, the necessary obvious changes may be made in the remainder of the frequency determining circuit in order to allow of what is in effect variable inductance tuning. Figure 2 shows only the cable with the tuning condenser TC.

If, instead of using a cable which is one quarter of the wave length long at the middle frequency, a cable which is one half the wave length at this frequency is used, a remotely situated variable condenser will act as though it were a capacity at the other end of the cable, and similarly a remotely situated variable inductance will act as though it were an inductance at the other end of the cable.

Similar results are obtained whether the cable be a quarter wave length long or an odd plurality of quarter wave lengths long and again similar results are obtained whether the cable be a half wave length long or any plurality of half wave lengths long, the principal difference occasioned by increasing the length of the cable from the quarter wave length or the half wave length arrangement respectively being that the tuning range which can be covered is decreased and the losses are increased.

Of course the invention is not limited to the precise form of frequency changer described nor indeed to the frequency determining tuned circuit of a local oscillator, for obviously the said invention may be used wherever a remotely controllable variable reactance effect in a high frequency circuit is required for tuning or similar purposes.

Another embodiment of the invention as applied to a multi-stage tunable multi-range radio receiver will now be described with reference to the accompanying Figure 3.

This receiver, which may be of any convenient known type, will for the sake of simplicity be assumed to comprise two cascaded high frequency stages which may be tuned over either of two wave length ranges, one from 200 to 350 metres and the other from 315 to 550 metres. In this receiver the aerial coil A is coupled to the usual grid coil GC1 of the first tube V1 of the receiver, which coil is connected between grid and cathode of the said tube. The plate of the said tube is connected through a choke CH1 to the source of anode potential (not shown) and is also coupled through a coupling condenser 2C to the grid of a second tube V2. The grid coil of the first tube is remotely tuned by means of an arrangement as follows:

The cathode of the first tube is earthed and connected to the screen or outer conductor OK1 of a tubular high frequency cable K1 whose central conductor IK1 is connected at the same end to the grid of the said first tube V1. The two conductors of the cable are, at the other end of said cable, connected to the input terminals of an artificial line or phase shifting network PS1 whose output terminals are connected to the input terminals of another artificial line or phase shifting network AL1. One of the output terminals of the second artificial line or phase shifting network AL1 is connected to one terminal of variometer TL1 whose other terminal is connected to the blade B1 of a two-position switch having two cooperating contacts X1, Y1, one (X1) of which is connected to the remaining output terminal of the second artificial line or phase shifting network AL1 and the other (Y1) of which is connected to a point between one of the output terminals of the first output artificial line PS1 and the corresponding input terminal of the second artificial line AL1. Thus when the switch is in one of its positions the variometer TL1 is connected across the grid coil GC1 of the first valve V1 through a line which consists of the cable K1 and the two artificial lines PS1 and AL1 in series, while if the switch is in its other position the second artificial line AL1 is short circuited, and the variometer TL1 is connected across the grid coil GC1 through only the cable K1 and the first artificial line PS1 in series. These input and output terminals of the artificial line which are on one side thereof are common and earthed to the screen or outer conductor of the cable as shown. Over the particular wave length ranges referred to if the electrical length of the cable K1 is chosen so that it produced a phase shift of about 27° at 265 metres (the midfrequency of the lower range) the first artificial line PS1 is designed to produce a phase shift of about 63°. Thus at 265 metres the electrical length including the first artificial line PS1 and the cable K1 will be substantially one quarter the working wave length. The phase shift of the second artificial line AL1 is so chosen that at 415 metres (which is the midfrequency of the upper range) the electrical length of the cable K1 together with the two artificial lines PS1 and AL1 will be again about one quarter of the wave length. Thus the variometer is reflected as a capacity at the grid coil of the first valve and operates as a tuning capacity for the two wave length ranges, the switch being put into one position for one wave length range and the other for the other, the position for the longer range being that on which both artificial lines are included effectively in circuit. The second tube V2 of the receiver has the usual grid coil GC2 between grid and cathode and this coil is again remotely tuned through a high frequency cable K2 and two artificial lines PS2 and AL2 and associated short circuiting switch B2, X2, Y2 by a second variometer TL2 the arrangement being similar to that employed for the first stage. The plate of the second tube V2 is choke-capacity coupled by means of the combination CH2, 3C, to the grid of the third tube V3 which is a demodulating detector and which has again a grid coil GC3 remotely controlled through a cable K3 artificial lines PS3, AL3, associated switch B3, X3, Y3, and variometer TL3, as above described. The three switches are mechanically coupled together so that they are uni-controlled and the three variometers may be similarly gang controlled. The gang controlling is indicated by dot and dash lines. In the specific example described, the cable provides about 27° of phase shift at 265 metres and such a phase shift would be obtained by an ordinary tubular high frequency cable about 50 feet long. Of course, for other lengths or designs of cable the extent of phase shift provided thereby may be different and in such cases the phase shift provided by the first artificial line will be such that when added to that provided by the cable, the over-all electrical length will be about one quarter of the working wave length at the middle of the lower frequency range. If desired, the switches and the variometers may be unicontrolled by a single handle in such manner that for the first 180° of the movement of the variometer control shaft the switches are in one position and an inductance variation from minimum to maximum is obtained while for the next 180° of movement the switches are in the other position and the full variation of inductance is again obtained. Such combined switch and variable reactance arrangements are, of course, known per se. The invention is not limited to the particular wave lengths above given for exemplification, and it would be possible to use a similar method for obtaining tuning over a long wave length range of the order of 1,000 to 2,000 metres. It is, however, believed that in general, for a multi-range receiver having a fairly short wave length range and a long wave length range, it will probably be found more convenient to provide additional coils for the long wave length range and to switch these in when required by mechanically or electrically operated remote control switches.

The invention is also applicable to coupling receiving aerials to remote receivers through cables. In general hitherto "cable" leads-in have largely been regarded as merely lumped capacities or attempts have been made to match the aerial load thrown on to the cable to the surge impedance thereof. In both cases the result is to restrict the over-all aerial input efficiency at the length of the cable lead-in which can be used, and also to increase the difficulty of gang-controlling the high frequency tunable stages of the receiver, since the cable will be associated with one of them and not with the others. By, however, employing the principles of this invention and treating the aerial as a reactive load and adjusting the equivalent cable length (by the term "equivalent cable length" is meant either the physical length of the cable in the case of an ordinary high frequency cable where the physical and electrical lengths are the same; or the electrical length of the cable plus any phase boxes in series therewith; or the electrical length of a low velocity cable together with that of any phase boxes in series therewith) it is possible to employ efficiently very much longer lengths of cable and at the same time to simplify the problems of ganging the receiver circuits.

In one such example in accordance with the invention and illustrated in the accompanying Figure 4 an aerial RA is coupled to the first tuned circuit LK of a two-range radio receiver (one of the ranges being a medium wave range and the other a long wave range) through a cable K whose electrical length (including that of any phase boxes PS and AL connected in series therewith also switching means SW for changing the wave range) is equal to one quarter of the working wave length at 200 metres. This electrical length will be equal to 1/40th of the working wave length at 2,000 metres. Accordingly for this case the aerial load, which is predominantly capacitative, will reflect in at the first circuit of the receiver as an inductance at 200 metres and as a capacity at 2,000 metres. It will be noted that with this arrangement the tuning range is actually increased as compared to that which would be obtained were the aerial not remote but directly coupled for under ordinary conditions an aerial load materially restricts the tuning range of the circuit with which it is associated (the first receiver circuit) as compared to that of other circuits succeeding the said first circuit.

A defect of the arrangement just described is that at the wave length at which the reflection conditions cause the load reflected to the receiver to change from that of an inductance (at a higher frequency) to that of a capacity (at a lower frequency) inefficiencies of aerial input may occur. It is however possible so to choose the phase change along the cable (making it between one quarter and one eighth of the working wave length long for the shortest wave length to be received) and so to choose the characteristic impedance of the cable as to avoid restricting the tuning range of the first receiver circuit and to keep the aerial input efficiency high all over the working wave length range.

In carrying out the invention use may be made of ordinary high velocity high frequency cables or low velocity cables may be used with advantage. In many cases, for example, in the case where a length of high velocity cable is required to be connected to a length of low velocity cable or in the case where a cable is employed to feed energy from a receiving aerial to a remote receiver, the problem of matching impedances may arise. Since, of course, the velocity in a cable is proportional to the reciprocal of the square root of the product of its inductance per unit length into its capacity per unit length, whereas the surge impedance of the cable is proportional to the square root of the quotient of the capacity per unit length into the inductance per unit length, it is difficult in some cases to design a low velocity cable without making the surge impedance high: that is to say, low velocity cables generally constitute high impedance lines. This difficulty may be met (as shown in the accompanying Figure 5) by joining a length of ordinary high velocity cable to a length of low velocity cable of higher impedance and in order that such joining may be electrically satisfactory use may be made of a length of what is sometimes termed "tapered" line at the juncture. In Figure 5 the length PQ represents high velocity cable, the length QR the tapered jointing section and the length RS represents low velocity cable. Such a tapered line should be so designed that the square root of the quotient of its capacity per unit length into its inductance per unit length (taken at one end) is equal to that of the cable to which it joins (at that end) while the square root of the quotient of the capacity per unit length into the inductance per unit length (taken at the other end) is similarly made equal to that of the cable which joins it at the said other end. The square root of the quotient of the capacity per unit length into the inductance per unit length is caused to vary smoothly from one end to the other of the tapered length, preferably according to a logarithmic law. This is indicated by way of example by the numbers marked at different points in Figure 5 the numbers representing the square root of the said quotient at the different places. By the use of such a tapered section of line reflection effects at joints may be avoided.

There will now be given a few examples of low velocity cables which may be employed in carrying out this invention. The velocity in a cable can be reduced either by increasing the capacity per unit length or the inductance per unit length or both. In general the inductance can conveniently be increased by winding the central conductor of the cable in helical form while the capacity can be increased by diminishing the inter-conductor space. Where a helical central conductor is used it is preferable to provide the outer conductor or sheath with a longitudinal slot to minimize eddy current losses. For example, in one construction of low velocity cable illustrated in the accompanying Figure 6 the inner conductor consists of a series of short helical coils ICC wound upon ebonite or other insulating sleeving ES and connected in series, the coils being spaced from one another longitudinally by insulating beads IBB and being housed in a sheath consisting of rubber covering ORC with an outer conductor OCG of copper gauze or the like. Such a cable is readily made flexible. Where the coils are wound upon lengths of sleeving the ends of the sleeves may be made interlocking, for example, they may be provided with portions which constitute ball and socket joints. In this case, the insulating beads may be dispensed with. Again, by the use of a suitable binding agent for the short series connected coils the said coils may be made self-supporting and the sleeving omitted.

In another construction (illustrated in the accompanying Figures 7 and 8) of flexible cable—which, like that just described, is also a low velocity cable—the inner conductor IC is of helical form and is wound upon a composite paper former PF built up of layers of paper tape made, as shown in Figure 8, of ladder-like form the lengths of tape being assembled at random and lightly cemented with a suitable adhesive. The wire is wound upon this paper core and the winding then lightly wrapped with paper insulation PI and the whole surrounded by a lead covering OLC.

In another form of low velocity cable the outer conductor is made of helical form. For example as illustrated in the accompanying Figure 9 a central conductor IK may be wrapped round with paper insulation PI and upon this insulation there my be wound a helical outer conductor HOK which is protected by being braided over with cotton braiding OCB or the like. Instead of braiding over the outer helical conductor with cotton the said outer conductor may be wrapped round with paper insulation and a gauze outer sheath, which may if desired be connected to the innermost conductor, may surround the outer layer of paper insulation. There are many other forms of low velocity cable which may be used in carrying out the invention, and in general a required low velocity will be obtained by increasing the inductance, e. g., by making one of the conductors of the cable or if desired both, of helical form. Although paper insulation has been referred to in the cable construction just described, other forms of insulation are possible—for example, hemp—and a helical inner conductor may be wound upon a hemp core instead of a paper core.

In another form of low velocity cable which may be used in carrying out the invention, and which is illustrated in Figure 10, an inner conductor HIK is wound helically upon a central glass tube IGT which is spaced at intervals by suitable insulating material SPI from a concentric outer copper tube COK. In one construction of cable as just described, and which was experimentally tested, the inner tube IGT was $\frac{3}{16}$ths'' in diameter, the helical conductor HIK was wound with 60 turns per inch and the outer copper tube COK was ½'' internal diameter, the outer diameter being ⅝ths''. A piece of such cable 21'' long, exhibited very sharp quarter wave length effects at 71 metres wave length and the measured characteristic impedance was 1,250 ohms. Such a piece of cable could be used as a sharply tuned circuit by short circuiting the remote end.

As regards the artificial lines or phase shift networks which may be used in carrying out this invention, these may be of any form well known per se, their design being in accordance with well known filter and impedance network design; for example they may be of low pass filter type as illustrated in the accompanying Figure 11 or of T section filter type as illustrated in the accompanying Figure 12 or of composite type possessing "constant impedance" properties as illustrated in the accompanying Figure 13, and so on.

Although in the illustrated arrangements concentric feeders or cables are shown—these cables may be regarded as equivalent to T networks and are thus of the asymmetric type—the invention is not limited to the use of such cables but can obviously be carried into practice with the aid of other forms of cable, notably symmetrical (twin wire) cables which may be regarded as equivalent to H networks.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:

1. A multi-range radio receiver arrangement comprising a receiver having at least two bands, a receiving aerial coupled to the input tuned circuit of the first stage of said receiver through a high frequency cable whose electrical length including an artificial line in series therewith is such that over one of the tuning ranges of the receiver the aerial load is reflected in the first circuit of said receiver as an inductance while for another of the ranges of the receiver the said load is reflected in as a capacity.

2. A receiver as claimed in claim 1 and wherein the electrical length of the cable is approximately one quarter of the working wave length at the middle of one of the tuning ranges and is approximately 1/40th of the working wave length at the middle of the other.

GEORGE MAURICE WRIGHT.
NOËL MEYER RUST.