June 20, 1950 G. H. BROWN 2,511,899

ANTENNA SYSTEM

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Fig. 2.

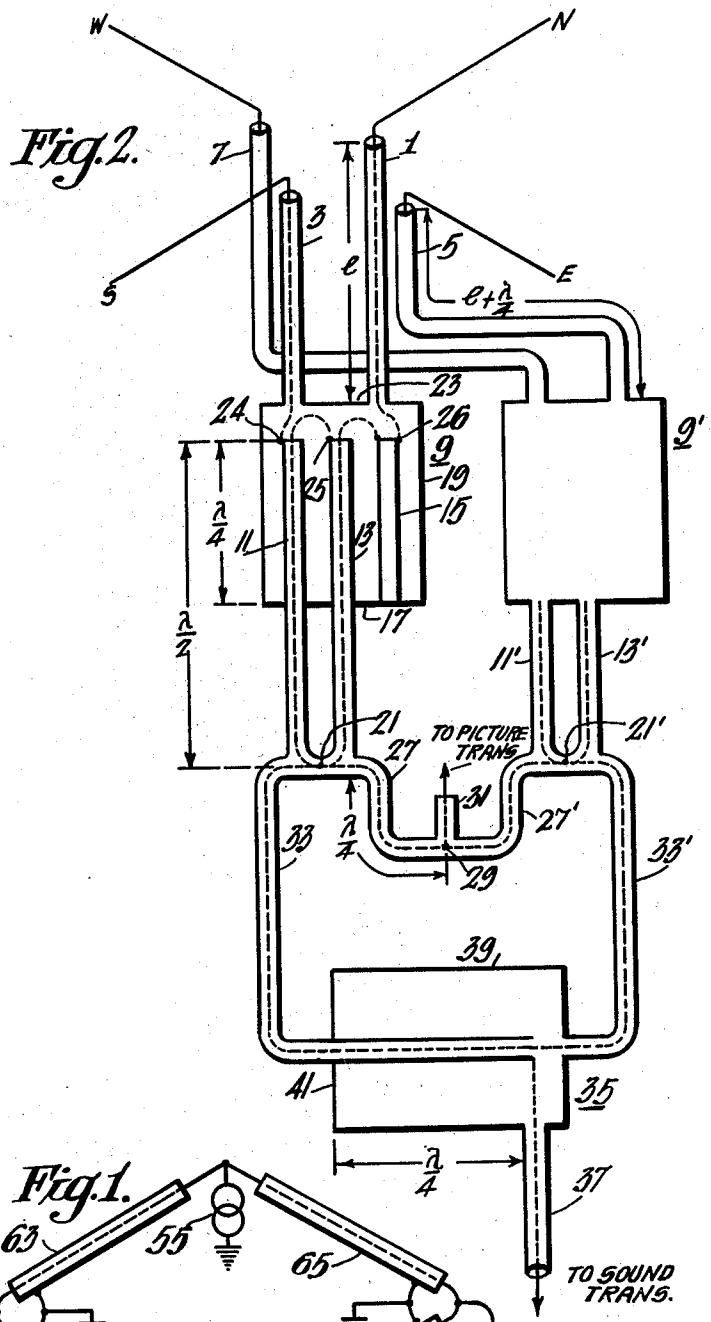
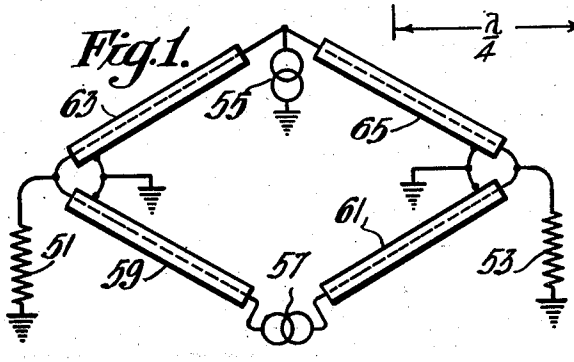


Fig. 1.



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ANTENNA SYSTEM

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8 Claims. (Cl. 250—33)

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This invention relates to radio frequency power networks wherein two independent sources, which must be electrically isolated from one another, are required to supply energy simultaneously to a common load device. Networks of the described type find application, for example, in television broadcast systems, wherein it is desired to transmit a picture signal and an accompanying sound signal from a single antenna. In order to prevent interchange of power between the sound and picture transmitters, it has been the practice to employ filters. Such filters require careful design, will operate only with sound and picture carrier frequencies for which they are designed, introduce a certain amount of loss, and introduce reactances in the system which make it difficult to design the overall system for efficient broad band operation which is necessary for high definition television.

It is the principal object of the present invention to provide a radio frequency network which will substantially isolate two sources from each other, while enabling them to supply a common load simultaneously.

Another object is to provide a system of the described type which does not rely upon filters or equivalent means for the function of isolation, and thus introduces a minimum of undesirable reactance in the system.

Another object is to provide an isolation network coupling a single antenna system to a transmitter and a receiver for operation independently of one another.

A further object of this invention is to provide an isolation network which is readily adaptable to the requirements of combined sound and television broadcasting.

Still another object is to provide a network of the described type which is conveniently applicable to antennas of the type including two separately excited groups of radiators, such as the turnstile.

The invention will be described with reference to the accompanying drawings, of which Figure 1 is a schematic diagram of an isolation network according to the invention,

Figure 2 is a schematic diagram of a sound and television broadcast antenna system embodying an isolation network in accordance with the invention.

The principle of the present invention is illustrated by Figure 1. A pair of identical loads, represented by equal resistors 51 and 53, are to be energized simultaneously and independently from sources 55 and 57. The lower end of each of the

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resistors 51 and 53 is grounded. The upper end of the resistor 51 is connected to one side of the source 57 through a coaxial line section 59. The upper end of the other resistor 53 is connected to the other side of the source 57 through a second coaxial line section 61. The line sections 59 and 61 are equal in length. The source 57 is electrically symmetrical or balanced with respect to ground, that is when one terminal is positive with respect to ground potential, the other terminal is negative by the same amount with respect to ground potential. The source 55 is unbalanced to ground, with its lower terminal grounded. The upper end of the source 55 is connected through line sections 63 and 65 respectively to the upper ends of the resistors 51 and 53. The line sections 63 and 65 are equal in length.

The operation of the system of Figure 1 is as follows: The terminal voltage of the source 57 is applied to the loads 51 and 53 in series through the line sections 59 and 61. The potentials at the upper ends of the resistors 51 and 53 are equal and opposite to each other, referred to ground potential. Thus the potential at the junction point of the lines 63 and 65, at the upper end of the source 55, is zero, referred to ground and no voltage is produced across the source 55 by the source 57. At the same time, the source 55 supplies the loads 51, 53 in parallel with each other through the lines 63, 65. The potentials produced at the upper ends of the loads 51 and 53 by the source 55 are equal. Therefore, no voltage is produced across the source 57 by the source 55. Thus it is apparent that each of the loads 51 and 53 is supplied by both sources 55 and 57 without any interaction between the two sources. The source 57 feeds the loads 51 and 53 asymmetrically with respect to ground, while the source 55 feeds the loads symmetrically with respect to ground.

Figure 2 shows the application of the system of Figure 1 to a sound and television broadcast antenna system. The antenna in this instance is illustrated as a single layer turnstile, comprising four orthogonally disposed horizontal radiator elements N, E, S and W. The two pairs N-S and E-W are excited as doublets, in quadrature phase relationship to each other, in order to provide horizontally polarized radiation with a field intensity which is substantially uniform in all directions throughout the horizontal plane of the radiators. Each doublet is balanced to ground, with current flowing into one element (e. g. the

radiator N) while an equal current flows out of the other radiator (S).

The radiators N, S, E and W are provided with separate coaxial feed lines 1, 3, 5 and 7 respectively. The lines 5 and 7 are made one-quarter wavelength longer than the lines 1 and 3 in order to provide the required quadrature relationship in excitation of the dipoles N-S and E-W. Actually the two lines 1 and 3 are the conductors of a balanced line to the dipole N-S, and the lines 5 and 7 constitute a balanced line to the dipole E-W.

Line balance convertors

The dipole N-S is connected through the lines 1 and 3 to the balanced terminals of a line balance convertor 9. The convertor 9 is of the type described in copending U. S. application Ser. No. 568,844, filed December 19, 1944 by G. H. Brown and O. M. Woodward, Jr., now U. S. Patent No. 2,473,328 issued June 14, 1949, and entitled Line balance convertors, and comprises two coaxial line sections 11 and 13 disposed in parallel relationship with each other and a cylindrical conductor 15, similar to the outer conductors of the line sections 11 and 13. The outer conductors of the line sections 11 and 13 are connected to each other and to the conductor 15 by a conductive plate 17, which acts also as the bottom closure of a shield 19 surrounding the balance convertor. The plate 17 is approximately one-quarter wavelength from the upper ends of the line sections 11 and 13, which are connected together at their lower ends at the point 21. The sections 11 and 13 are approximately one-half wavelength long over all, and the conductor 15 is approximately one-quarter wavelength long. The upper end of the shield 19 is closed by a plate 23 into which the feed lines 1 and 3 extend.

The outer conductors of the lines 1 and 3 are grounded to the shield plate 23. The inner conductor of the line 1 is connected to the end of the cylindrical conductor 15, and the inner conductor of the line 3 is connected to the end of the outer conductor of the line section 11. The inner conductor of the line section 11 is connected at 25 to the outer conductor of the line section 13, and the inner conductor of the line section 13 is connected to the end of the conductor 15.

The radiators E and W are connected through the lines 5 and 7 to a line balance convertor 9', identical with the convertor 9. The half-wave lines 11' and 13' of the convertor 9' are connected together at the junction point 21', which corresponds to the point 21 of the N-S circuit.

The points 21 and 21' are supplied with radio frequency power through a network described hereinafter. For the present, it is sufficient to say that points 21 and 21' are unbalanced to ground, i. e. the outer conductors are at ground potential and the radio frequency input voltage is applied between the inner conductor and ground. Since the operation of the E-W balance convertor circuit is identical with that of the N-S circuit, only the latter will be described.

Balance convertor operation

The voltage applied to the point 21 reaches the upper ends of the line sections in phase because the two sections are of equal lengths. The upper quarter wavelength portions of the outer conductors of the sections 11 and 13, being connected together at the plate 17, cooperate to act as a quarter wave short-circuited parallel line, presenting a high impedance at the upper ends

24 and 25. Each of the outer conductors of line sections 11 and 13 cooperates similarly with the conductor 15, so that the upper end 26 of the conductor 15 is effectively isolated from ground, as are the points 24 and 25. Since the voltages across the upper ends of the sections 11 and 13 are in phase, the voltages, referred to ground potential, of the outer conductor of the line 11 at the point 24 is 180° out of phase with that of the inner conductor of the line 13 at the point 25. The lines 3 and 1 are thus excited in opposite phases. The flow of current at a given instant may be traced up through the inner conductors of lines 11 and 13, the current on the inner conductor of line 11 flowing back down the inside of the outer conductor of line 13 and that on the inner conductor of line 13 flowing up the line 1 to the radiator N. Current flowing down the line 3 from the radiator S goes down the inside of the outer conductor of the line 11.

Convertor circuit reactance compensation

The quarter wave end portions of line sections 11 and 13, and the conductor 15, present zero reactance and substantially infinite impedance at the frequency at which the lengths are exactly one-quarter wavelength. At other frequencies, the impedance is lower and there is reactance, of a value and sign depending upon the deviation from the resonant frequency. The reactance versus frequency characteristic of the elements 11, 13 and 15 is similar to and produces the same effects as a short-circuited quarter wave stub line connected across the upper end of each of the line sections 11 and 13. These reactances are compensated, throughout a very wide frequency band, by the method described and claimed in copending U. S. Patent application Ser. No. 551,247, filed August 25, 1944 by G. H. Brown, now U. S. Patent No. 2,419,985 issued May 6, 1947, and entitled Reactance compensation.

The lines 1 and 3 are assumed to be matched in impedance to the radiators N and S. Denoting the impedance level as Z_0, the characteristic impedances of the lines 1 and 3 are Z_0 and the impedances presented to the upper ends of the line sections 11 and 13 are also Z_0. By making the surge impedances of the lines 11 and 13 somewhat higher than Z_0, in accordance with the relationship between the impedance level Z_0 and the characteristic impedance of the equivalent shunt reactance element representing the characteristic of the convertor 9, the reactance may be balanced by shunting the lower ends of the line sections 11 and 13 with a similar reactance. In accordance with the teachings of said U. S. application Ser. No. 551,247, the quantity

$$\frac{Z_c}{Z_0}$$

should lie between 90 and 100 percent of

$$\frac{1+\sqrt{1+4\left(\frac{Z_s}{Z_0}\right)^2}}{2\frac{Z_s}{Z_0}}$$

wherein Z_s is the surge impedance of the equivalent short-circuited stub shunted across the upper end of each of the line sections 11 and 13, and Z_c is the surge impedance of each of the line sections 11 and 13. The balancing reactance of the lower ends of line sections 11 and 13 is provided by the elements of the isolation circuit described below. The reactance cancellation works both ways, i. e. the reactances of the isola-

tion circuit are balanced by the convertor reactance, and vice versa. It will be apparent to those skilled in the art that the spacings of the sections 11 and 13 and the conductor 15 within the convertor 9 must be made such that the resulting shunt reactances are identical with the reactances presented by the isolation circuit.

Isolation network

The feed points 21 and 21' of the N-S and E-W circuits respectively are connected through coaxial lines 27 and 27' to a junction point 29. Also connected to the point 29 is a coaxial line 31 which runs to a television picture transmitter, not shown. The lines 27 and 27' are each substantially one-quarter wavelength, or an odd integral number of quarter wavelengths long, and are of characteristic impedance Z_0. They should be equal in length, or differ in length by an integral number of wavelengths. The feed points 21 and 21' are also connected through lines 33 and 33' to the balanced output terminals of a line balance convertor 35. The lines 33 and 33' are each one-half wavelength, or an integral number of half wavelengths long.

The line balance convertor 35 includes an unbalanced input line 37 which extends to a sound transmitter, not shown. This line, as well as the line 31 to the picture transmitter, may be of any required length. Both of the lines 31 and 37 are of Z_0 characteristic impedance. The terminal quarter wavelength section of the line 33 is surrounded by a cylindrical conductor 39, closed at its end by disc 41 through which the line 33 extends. The outer conductor of the line 33 is connected to the disc 41. The connections of the sound and picture transmitters to the network may be interchanged without substantially affecting the operation of the system. The inner conductor of the line 33 is connected to that of the line 33'. The inner conductor of the line 37 is connected to the outer conductor of the line 33. The outer conductors of the lines 33 and 33', and 37 are connected to the sleeve 39.

The outer conductor of the line 33 cooperates with the sleeve 39 as a quarter wave coaxial line, short-circuited by the disc 41, and presents a high impedance at the end of the line 33, effectively isolating the end of the outer conductor from ground. Current flowing up on the inner conductor of the line 37 goes along the outer conductor of the line 33 to the disc 41, inducing an equal and opposite current in the inner conductor of the line 33. This current flows down the inner conductor of the line 33 and up the inner conductor of the line 33'. Thus the points 21 and 21' are fed 180° out of phase with each other from the input line 37. The lines 33 and 33' are in series with each other across the line 37.

Operation of isolation network

The impedances looking into each of the lines 11 and 13 and 11' and 13' from the points 21 and 21' are Z_0. Therefore, the impedances looking from the points 21 and 21' toward the convertors 9 and 9' are $Z_0/2$, since the lines 11 and 13 are in parallel. Owing to the impedance inverting characteristics of quarter wave lines, the impedances are transformed to

$$\text{Input } Z = \frac{(\text{Line } Z)^2}{\text{Load } Z} = \frac{Z_0^2}{\frac{Z_0}{2}} = 2Z_0$$

looking into the lines 27 and 27' from the junction 29. Since the lines 27 and 27' are connected in parallel to this point, the impedance there is Z_0, and is matched by the picture input line 31.

The half wave lines 33 and 33' present the same impedances $Z_0/2$ at their input ends at the convertor 35 as they look into at the points 21 and 21'. The input ends are connected in series in the convertor 35, presenting a total impedance $Z_0/2+Z_0/2$ or Z_0 to the sound input line 37.

As stated above the reactances of the convertors 9 and 9' are balanced by those presented to the points 21 and 21' by the isolation circuit. The latter reactances are principally comprised of the reactance presented at the points 21 and 21' by the half wave lines 33 and 33'.

The input from the picture input line 31 reaches the points 21 and 21' in phase because the lines 27 and 27' are of equal lengths. The picture input will not travel down the sound input line 37, since it reaches the inner and outer conductors of the line 37 in phase, through the lines 33 and 33', and no voltage across the line 37 can be produced by the picture input.

The input from the sound input line 37, on the other hand, reaches the points 21 and 21' out of phase, and through the lines 27 and 27', the point 29. Since the voltages arriving at the point 29 from the sound transmitter are 180° out of phase, the resultant voltage at the point 29 is zero and no energy from the sound transmitter flows into the line 31. Thus the sound and picture input lines are effectively isolated from each other, although each is coupled efficiently to the antenna system. The fact that the points 21 and 21' are in phase for the picture signal and out of phase for the sound signal is of substantially no importance. The only effect is that the turnstile phase rotation is clockwise for one signal and counter-clockwise for the other.

Summary

The invention has been described as embodied in a combined television and sound broadcast antenna system, for transmitting both sound and picture signals from a common radiator system. It is to be noted, however, that the invention may find other applications in systems requiring a common load or common loads to be supplied by independent sources which must be isolated from one another, or conversely in systems wherein common sources supply independent loads. Briefly, two feed points are supplied in opposite phases by one source through a line balance convertor or the equivalent. The same two feed points are supplied in phase by the second source. Energy from one source will arrive through the feed points at the other source by two paths; the voltage transmitted through one path will be 180° out of phase with that transmitted through the other. Thus each source is balanced out with respect to the other, and no interchange of energy can occur between them. In the described arrangement, impedance matching is obtained by simple arrangement of transmission lines, and unavoidable reactances presented by the line balance convertors are substantially neutralized, permitting efficient broad-band operation of the system.

I claim as my invention:

1. A radio antenna system for excitation from two independent input circuits simultaneously, including two groups of radiators, each electrically balanced to ground, two pairs of balanced lines, one pair connected to each of said radiator

groups respectively, two line balance convertors, one connected to each of said pairs of balanced lines respectively, each of said balance convertors including two half wavelength line sections, one having its outer conductor connected at its upper end to one of said balanced lines and the other having its inner conductor connected at its upper end to the other of said balanced lines, the lower ends of said half wave line sections being connected in parallel with each other to constitute a feed point, means connecting the outer conductors of said half wavelength line sections together approximately at their mid-points, whereby the upper portions of said outer conductors act as a quarter wave parallel line shunting said balanced lines, quarter wavelength lines connected between one of said input circuits and said feed points respectively, half wave lines connected at one end respectively to said feed points, a line balance convertor having its balanced terminals connected between the other ends of said last-mentioned half wave lines, and its unbalanced circuit connected to the other of said input circuits, the design of said last-mentioned balance convertor being such that the resonance characteristics presented thereby at said feed points are substantially the same as those presented by said first-mentioned balance convertors at their balanced terminals, said first-mentioned half wave sections having characteristic impedances determined in accordance with said resonance characteristics so as to effect substantial cancellation of the reactances of said balance convertors.

2. A network for radio antenna systems including a pair of radio frequency feed points to be simultaneously supplied with energy from a pair of independent radio frequency inputs, said input circuits comprising coaxial transmission lines having inner and outer conductors, two equal length transmission lines connecting said feed points to one of said inputs to transfer energy therefrom to said feed points in the same phase relationship, an additional transmission line connected to one of said feed points, a further transmission line connected to the other of said feed points, the inner conductors of said additional and said further transmission lines being connected together at the ends remote from said feed points, means to connect the inner conductor of the other of said input circuits to the outer conductor of said additional transmission line, and means arranged to form a transmission line stub, to connect the outer conductor of the other of said input circuits to the outer conductor of said further transmission line and to the outer conductor of said additional transmission line at a point a quarter-wave length at the operating frequency from the end thereof to transfer energy from said other input circuit to said feed points in anti-phase relationship.

3. A net work for radio frequency systems including a pair of radio frequency outputs to be simultaneously supplied with energy from a pair of radio frequency inputs to be isolated from each other, said inputs comprising coaxial transmission lines having inner and outer conductors, two equal length transmission lines connecting said outputs to one of said inputs to transfer energy to said outputs in the same phase relationship, an additional coaxial transmission line connected to one of said outputs, a further coaxial transmission line of the same length as said additional transmission line connected to the other of said outputs, the inner conductors of said additional and said further transmission lines being connected together at the ends remote from said outputs, means to connect the inner conductor of the other of said inputs to the outer conductor of said additional transmission line, and stub means arranged to connect the outer conductor of the other of said inputs to the outer conductor of said further transmission line and to the outer conductor of said additional transmission line at a point a quarter-wave length at the operating frequency from the end thereof to transfer energy from said other input to said outputs in anti-phase relationship.

4. An antenna system including a pair of radio frequency feed points to be simultaneously supplied with energy from a pair of independent radio frequency input circuits, each of said input circuits comprising a coaxial transmission line having an outer conductor maintained at a given reference potential and an inner conductor, means to prevent the transfer of energy from one of said input circuits to the other comprising two equal length transmission lines connecting said feed points to one of said input circuits to transfer energy therefrom to said feed points in the same phase relationship, an additional transmission line connected to one of said feed points, a further transmission line of the same length as said additional transmission line connected to the other of said feed points, the inner conductors of said additional and said further transmission lines being connected together at the ends remote from said feed points, means to connect the inner conductor of the other of said input circuits to the outer conductor of said additional transmission line, and a conductor surrounding a portion of said additional transmission line to connect the outer conductor of the other of said input circuits to the outer conductor of said further transmission line and the outer conductor of said additional transmission line at a point a quarter-wave length from the end thereof to transfer energy from said other input circuit to said feed points in anti-phase relationship.

5. A radio antenna system for simultaneous excitation from two independent input circuits unbalanced with respect to a given reference potential and including two groups of radiator elements, comprising a pair of transmission lines coupled to each group of radiator elements and connected in parallel with each other to constitute a feed point, quarter-wave length lines connected between one of said input circuits and said feed points respectively, half-wave coaxial transmission lines connected at one end respectively to said feed points, means to interconnect the inner conductors of said half-wave lines means to interconnect the end of the outer conductor of the other end of one of said half-wave lines and the terminal of the other of said input circuits remote from said given reference potential, and a conductor coaxially arranged about said one of said half-wave lines to form a quarter-wave stub section, said conductor being connected to the outer conductor of the other half-wave line at the end thereof, to the terminal at reference potential of said other input circuit and to the outer conductor of the first said half-wave line substantially at its mid-point.

6. A radio antenna system for simultaneous excitation from two independent input circuits including two groups of radiators, transmission line sections coupled to said radiators and connected in parallel with each other to constitute a feed point, equal length lines connected between one of said input circuits and said feed points re-

spectively, further equal length lines connected at one end respectively to said feed points, and apparatus connected between the other ends of said further equal length lines and the other of said input circuits to induce equal and opposite currents in said further equal length lines in response to excitation in said other input circuit.

7. A radio antenna system for simultaneous excitation from two independent input circuits, including two groups of radiators, transmission lines coupled to each group of radiators and connected in parallel with each other to constitute a feed point, quarter-wave length lines connected between one of said input circuits and said feed points respectively, half-wave lines connected at one end respectively to said feed points, and apparatus connected between the other ends of said last-mentioned half-wave lines and the other of said input circuits to induce equal and opposite currents in said further equal length lines in response to excitation in said other input circuit.

8. A radio antenna system for simultaneous excitation from two independent input circuits, including two groups of radiators, each electrically balanced to ground, two pairs of balanced lines, one pair connected to each of said radiator groups respectively, two line balance convertors, one connected to each of said pairs of balanced lines respectively, each of said balance convertors, including two half-wave length line sections, one having its outer conductor connected at its upper end to one of said balanced lines and the other

having its inner conductor connected at its upper end to the other of said balanced lines, the lower ends of said half-wave line sections being connected in parallel with each other to constitute a feed point, means connecting the outer conductors of said half-wave length line sections together approximately at their mid points, whereby the upper portions of said outer conductors act as a quarter-wave parallel line shunting said balanced lines, quarter-wave length lines connected between one of said input circuits and said feed points respectively, equal length lines connected at one end respectively to said feed points, a line balance converter having its balanced terminals connected between the other ends of said last-mentioned equal length lines, and its unbalanced circuit connected to the other of said input circuits.

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