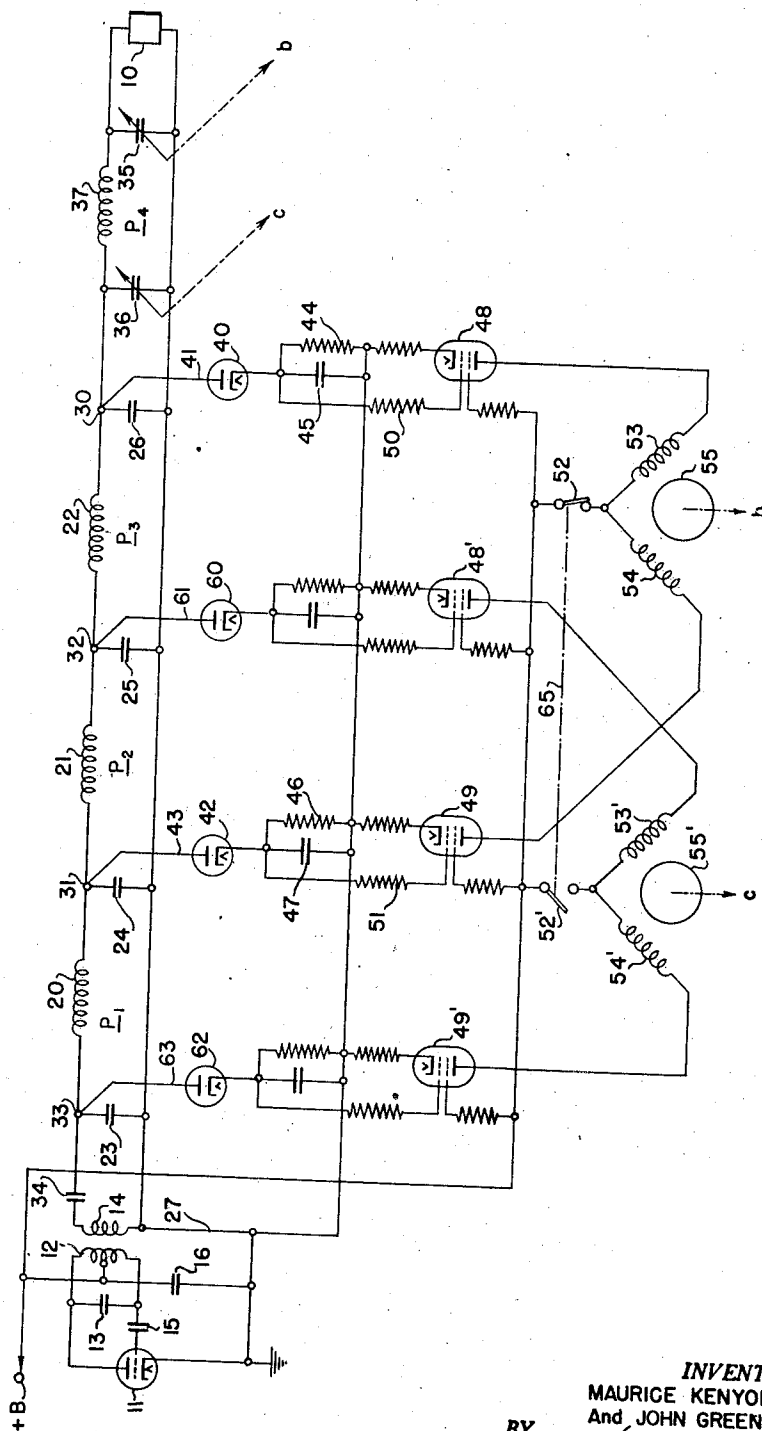


Dec. 21, 1948.

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IMPEDANCE MATCHING ARRANGEMENT

2,456,800

Filed Aug. 3, 1945



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2,456,800

IMPEDANCE MATCHING ARRANGEMENT

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Application August 3, 1945, Serial No. 608,686
In Great Britain December 1, 1944

14 Claims. (Cl. 178-44)

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This invention relates, in general, to wave-translating arrangements for operation at short wave lengths, being especially directed to arrangements including a guide for electromagnetic waves effective to establish current and voltage conditions along its length in accordance with its operating wave length and the characteristics of a load impedance connected to the guide at a predetermined point. The expression "a guide for electromagnetic waves" as used throughout this description and in the appended claims is intended to be a generic expression and is intended to mean a transmission line of the parallel-wire or coaxial type, an artificial or simulated transmission line, a wave guide, or similar signal-translating network.

Arrangements of the type under consideration are well known in the art and have been utilized in a variety of installations. The present invention is subject to a corresponding variety of applications but, for convenience, only a limited number of such applications are to be described in detail.

Consider, for example, the use of a transmission line for transferring energy from a short-wave source, such as an oscillation generator, to a load impedance in a system where a direct coupling between the source and the load is not feasible. For optimum operation, the line must couple the load to the source with matched impedances so as to obtain uniform distribution of current and voltage along the line and maximum energy transfer to the load. This criterion of matched impedances is well recognized. It follows from the fact that if an impedance mismatch occurs between the line and the load impedance, standing waves of current and voltage are set up along the line. The characteristics of the standing waves are determined by the degree or extent of impedance mismatch and the operating wave length. At voltage antinodes of the standing wave, large dielectric losses and even corona losses may occur while at current antinodes large ohmic losses may be encountered. Thus, the necessity of suppressing standing waves becomes apparent if high efficiency is to be obtained in the system. Suppression of such standing waves may be accomplished, as already indicated, by securing proper conditions of impedance matching.

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In order to establish the desired impedance relations, it has been proposed to employ two transformers, one for coupling the line to the source and the other for coupling the line to the load impedance. The transformation ratios of the transformers are selected so that the impedances reflected into the line from the source and the load correspond with or match the characteristic impedance of the line. While such arrangements are satisfactory for many installations, they are subject to an operating limitation which may be undesirable in certain cases. For example, the impedance of the load may vary during the operation of the system causing mismatched impedances and establishing standing waves of current and voltage in the line with the inherent losses incident thereto.

A system quite similar to that described in the preceding paragraphs is also frequently employed as a means for obtaining impedance measurements at ultra-short wave lengths. In making impedance measurements, an unknown impedance is coupled to an oscillation generator through a line arrangement and the distribution of current and voltage along the line is studied to obtain an indication of the impedance characteristics of the load. Where uniform distribution of current and voltage is found, the load impedance is then known to correspond with that of the line. On the other hand, from the standing waves of current and voltage which follow when the line and load are mismatched, standing-wave ratios may be computed and utilized in conjunction with the position of the standing wave along the line to ascertain the characteristics of the load impedance. In such a case, computations may be made on the basis of well-known impedance formulae relating the current and voltage distribution along the line to its terminating impedance. In certain systems the computed standing-wave ratios are converted into characteristics of the load impedance through the use of known charts which correspond to graphical solutions of the transmission-line formulae. While impedance-measuring arrangements of this type are satisfactory, they require a certain amount of computation which it is desirable to eliminate.

It is an object of the present invention, therefore, to provide a wave-translating arrangement which substantially avoids one or more of the

above-mentioned limitations of prior arrangements.

It is another object of the invention to provide a wave-translating arrangement including a guide for electro-magnetic waves and an improved system for compensating the effective characteristics of a load impedance connected to the guide to establish desired current and voltage conditions therealong.

It is a specific object of the invention to provide a wave-translating arrangement including a guide for electro-magnetic waves and an improved system for maintaining a desired impedance relation between the guide and a load impedance connected thereto.

In accordance with the invention, an electro-magnetic wave-transmitting arrangement comprises a guide for electromagnetic waves effective to establish current and voltage conditions along its length in accordance with its operating wave length and the magnitude and phase angle of a load impedance connected to the guide at one point. There are provided a first pair of pickup devices coupled to the guide for developing a first control effect determined by the ratio of predetermined ones of the current and voltage conditions at two selected points so spaced along the guide with respect to the aforesaid one point that the first control effect varies with the effective magnitude of the load impedance. A second pair of pickup devices, including at least one device in addition to the first-named pair, is included in the arrangement and coupled to the guide for developing a second control effect in response to the ratio of predetermined ones of the current and voltage conditions at two selected points so spaced along the guide with respect to the aforesaid predetermined point that the second control effect varies with the effective phase angle of the load impedance. The arrangement has means for utilizing the first and second control effects so to vary the effective magnitude and phase angle of the load impedance that the above-mentioned ratios approach predetermined values.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

The single figure of the drawing represents a wave-signal system including a translating arrangement embodying the present invention.

Referring now more particularly to the drawing, the arrangement there represented includes a wave-translating arrangement in accordance with the invention for transferring signal energy from a short-wave oscillation generator to a load impedance 10. The oscillation generator is of the Hartley type and is provided by a triode vacuum tube 11 and an associated wave-length-determining circuit including an inductor 12 and a condenser 13. The inductor 12 forms the primary winding of a transformer 12, 14 and condenser 13 may be comprised in whole or in part of the distributed capacitance of winding 12, the stray capacitance of tube 11 and other stray capacitance effects. The anode of tube 11 is directly coupled with one terminal of the wave-length-determining circuit while the other terminal thereof is coupled to the control electrode through a blocking condenser 15. The cathode of tube 11 is directly coupled to a tap on winding 12 through a condenser 16, and a source of space

current, indicated +B, is applied to the anode of the tube through this tap.

The wave-translating arrangement for applying the signal output of oscillation generator 11 to load impedance 10 comprises a guide for electromagnetic waves which is effective to establish current and voltage conditions along its length in accordance with its operating wave length and the characteristics of load impedance 10. For the illustrated embodiment, this guide is in the form of a simulated transmission line and will be referred to as such throughout the remainder of this description. The transmission line comprises series-connected inductors 20, 21 and 22 as well as shunt-connected condensers 23, 24, 25, and 26. The series and shunt reactance elements are arranged in conventional manner forming three cascaded π -networks P₁, P₂ and P₃. The parameters of these networks are selected with reference to the desired operating wave length of the system to introduce a phase shift of 45 electrical degrees to an applied signal so that each network has an effective electrical length of one-eighth of the operating wave length. Additionally, the selection of the networks is made so that the transmission line has a characteristic impedance of a predetermined value. One side of the line is connected to ground through a conductor 27. The input terminal 33 of the line is connected by means of a condenser 34 to the secondary winding of transformer 12, 14, this transformer being designed to couple the line to oscillation generator 11 with matched impedances.

A π -type impedance-matching section P₄ couples the load impedance 10 to one point, specifically output terminal 30, of the transmission line. This impedance-matching section includes first and second adjustable elements for compensating a first and second characteristic, respectively, of the load impedance. The first and second characteristics of the load impedance referred to are such as to define the nature of the load and may, for example, constitute the magnitude and phase angle, the resistance and reactance, or the conductance and susceptance of the load. For the particular embodiment under consideration, the adjustable elements of section P₄ are a shunt condenser 35 which compensates for the magnitude of load impedance 10 and a shunt condenser 36 for compensating the phase angle of the load impedance. This π -section is completed by a series inductor 37 interposed between its shunt elements 35 and 36. Such a section is well-known in the art. Generally, its series element is arbitrarily selected and the shunt elements have the values required to match properly a pair of impedances connected at the opposing terminals of the section.

A first pair of pickup devices is coupled to the line for developing a first control effect determined by the ratio of predetermined ones of the current and voltage conditions at two selected points along the line. The selected points are spaced with respect to load terminal 30 so that this first control effect varies at least in part with variations in a first characteristic, specifically the magnitude, of load impedance 10. This pair of pickup devices comprises a diode rectifier 40 coupled by way of connection 41 to the load terminal 30 of the line, and a second diode rectifier 42 connected over a connector 43 to terminal 31 which is common to π -sections P₁ and P₂. The load circuit of diode 40 is provided by the parallel combination of a resistor 44 and a condenser 45. Diode 42 has a similar load circuit consisting of

elements 46 and 47. The signal outputs obtained from these load circuits are applied to the control electrodes of amplifiers including tubes 48 and 49 through resistors 50 and 51, respectively. The source of space current +B is applied to the anode electrodes of tubes 48 and 49 through a switch 52 and differential field windings 53 and 54, respectively, of a reversible direct-current motor, schematically represented at 55. The cathodes of the amplifiers are grounded through self-biasing resistors, and screen potentials are applied to the screen electrodes through conventional dropping-off resistors.

The wave-signal arrangement comprises a second pair of pickup devices including at least one device in addition to the first pair 40 and 42. As represented in the drawing, the second pair of devices is in addition to the first pair 40 and 42 and comprise the additional diodes 60 and 62. Diodes 60 and 62 are coupled to the line for developing a second control effect determined by the ratio of predetermined ones of the current and voltage conditions at two selected points so spaced with respect to load terminal 30 that this second control effect varies with variations in a second characteristic, namely, the phase angle of the load impedance 10. To this end, diode 60 is coupled to the common junction 32 of π -sections P_2 and P_3 through a connector 61 while diode 62 is connected with the input terminal 33 over a conductor 63. The load circuit of diode 60 is similar to that of diode 40 and its connection with an amplifier including a tube 48' is identical with the coupling between the load circuit of diode 40 and the amplifier 48. Likewise, the circuits associated with diode 62 and a further amplifier 49' are the same as those described in connection with diode 42 and amplifier 49. The anodes of amplifiers 48' and 49' are coupled to the space current source +B through a switch 52' and differential winding 53' and 54', respectively, of a second motor 55', which is similar to motor 55.

Motor 55 has a driving connection with the adjustable element of condenser 35 of impedance-matching section P_4 , as indicated by the broken line b-b. In like manner, motor 55' has a driving connection with the adjustable element of condenser 36, as indicated by broken line c-c. These driving connections constitute means for utilizing the first control effect derived by pickup devices 40 and 42 and for utilizing the second control effect derived by pickup devices 60 and 62 so to vary the operating conditions of the wave-translating arrangement that the ratios of current and/or voltage at the pickup points approach predetermined values. More specifically, the driving connections permit motors 55 and 55' to adjust the impedance-matching section P_4 to compensate, at least in part, the magnitude and phase angle of load impedance 10 to obtain desired ratios of current and voltage along the line.

Switches 52 and 52' may have a mechanical unicontrol, designated by broken line 65, for opening and closing the switches in alternation.

In considering the operation of the described system, it will be assumed initially that the adjustable elements 35 and 36 of the impedance-matching section P_4 couple load impedance 10 to load terminal 30 of the transmission line with matched impedances at the selected operating wave length of the system. As the coupling between the oscillation generator 11 and the input terminals of the line is designed to effect impedance matching at this end of the line, the load

impedance 10 is coupled to the oscillation generator through the agency of the line with impedance matching. When such a condition exists, no standing waves of current or voltage are encountered on the transmission line. Instead, the current and voltage are uniformly distributed therealong so that pickup devices 40, 42, and 60, 62 pick up the same amount of signal energy. The circuits associated with each such pickup device are identical. Consequently, the same signal voltage is established on the control electrodes of each of amplifiers 48, 49 and 48', 49'. If unicontrol 65 is operated, closing switch 52, like currents traverse the field windings 53 and 54 of motor 55. For this condition the motor experiences equal and opposite field fluxes and remains in a condition of rest so that no adjustment is effected of shunt condenser 35 of the impedance-matching section. When unicontrol 65 is adjusted to its alternate position closing switch 52', similar conditions are established for motor 55'. Hence, no adjustment is effected of the remaining condenser 36 of the impedance-matching section. In other words, the pickup devices and the associated control system exert no influence on the impedance-matching section so long as load impedance 10 is properly matched through the transmission line to the oscillation generator.

In the event that the impedance of load 10 varies in magnitude or phase angle the first-described condition of impedance matching no longer exists. Standing waves of current and voltage are then established along the transmission line in accordance with the operating wave length and the present magnitude and phase angle of load impedance 10. In view of the described effective electrical lengths of sections P_1 , P_2 and P_3 of the line, there is a difference of one-eighth of a wave length of the standing waves between points 30 and 32, 32 and 31, 31 and 33 along the line. For this condition, the amounts of signal energy picked up by devices 40, 42 and 60, 62 have such relative values or ratios that by alternately opening and closing switches 52 and 52' the motors 55 and 55' are operated to adjust impedance-matching section P_4 and re-establish a condition of impedance-matching. This will be apparent from the following consideration in which the voltage conditions established along the line by an impedance mismatch are to be explained. The discussion is to be restricted to the voltage aspects for convenience only. It will be immediately apparent to those skilled in the art that corresponding current conditions always exist along the line when standing waves of voltage are found. Hence, the signal ratios obtained by the pickup devices may be ratios based upon current and/or voltage observations of the standing waves along the line, but the following is predicated upon ratios of observed voltages.

It may be demonstrated that, when load impedance 10 is purely resistive but mismatched with the transmission line, the resulting standing wave of voltage is symmetrical with respect to the quarter wave length point or terminal 31. This means that at equi-spaced points from terminal 31 like conditions of voltage are encountered on the line. For example, at the one-eighth wave length terminal 32 and at the three-eighth wave length terminal 33, similar conditions of voltage exist. As a consequent, in view of a purely resistive load of any magnitude, pickup devices 60 and 62 derive the same amount of signal voltage and exert no control effect on the adjustable impedance-matching section P_4 . However, for any

resistive load which is mismatched with the line the voltage conditions at points such as load terminal 30 and the quarter wave length terminal 31 are unequal. It may be shown that, with a resistive load having a magnitude exceeding the characteristic impedance of the line, diode 40 picks up higher values of signal voltage than diode 42. On the other hand, for resistive loads less than the characteristic impedance of the line, the reverse condition prevails, that is, diode 42 picks up a larger signal voltage than diode 40. In view of the differential windings 53 and 54 of motor 55 the resultant field or control effect established for the motor 55 by the diodes 40 and 42 varies in opposite senses with deviations in purely a resistive load in opposite directions from the characteristic impedance of the line.

On the other hand, in the presence of a purely reactive load having a magnitude equal to the line impedance, the resulting standing wave of voltage is symmetrical with respect to the one-eighth wave length terminal 32. Therefore, with a purely reactive load of such magnitude, corresponding conditions of voltage are established at terminals 30 and 31 which are equi-spaced one-eighth of a wave length from terminal 32. It is thus apparent that, with a purely reactive load equal to the line impedance, diodes 40 and 42 derive like amounts of signal voltage so that motor 55 exerts no effect on the impedance-matching network P₄.

The conditions of voltage encountered at the one-eighth wave length terminal 32 and at the three-eighth wave length terminal 33 are unequal when the load impedance 10 is purely reactive irrespective of its magnitude. Diode 60 derives the greater signal voltage for an inductive load, while diode 62 derives the greater signal voltage for capacitive reactive loads. Consequently, the control effect established by differential windings 53' and 54' varies in opposite senses with deviations in opposite directions of the reactive component or phase angle of the load impedance from the reference phase angle of zero electrical degrees.

In view of the foregoing explanation of the conditions of voltage obtained at the one-eighth wave length points 30, 31, 32 and 33, motors 55 and 55' are controlled to adjust the impedance-matching section P₄ to maintain a condition of impedance matching between the load 10 and the transmission line. More specifically, the control effect produced by the windings 53 and 54 is determined both in magnitude and sense by the ratios of voltage at two selected points 30 and 31 along the line. This control effect, by causing motor 55 to rotate in a particular direction, adjusts condenser 35 to compensate the magnitude of the load impedance 10. In similar fashion, the control effect exerted on motor 55' is determined by the ratios of voltage at the selected points 32 and 33 and adjusts condenser 36 to compensate the phase angle of the load impedance 10. The compensation in magnitude and phase angle is in a direction to cause the ratios of voltage measured at the selected points 30—31 and 32—33 to approach unity. With unity signal ratios at the selected points, uniform voltage distribution is established on the line indicating the desired condition of impedance matching between the load impedance 10 and the generator 11.

Considering a particular case in which the load impedance 10 is mismatched with the line, representing both an improper magnitude and phase angle, assume unicontrol 65 is operated to close switch 52'. Any control effect established by windings 53' and 54' in view of the difference in

signal level of diodes 60 and 62 causes motor 55' to rotate and adjust condenser 36 in a direction tending to equalize the signal voltages applied to diodes 60 and 62. The rotation of motor 55' is interrupted when the adjustment of condenser 36 causes unity ratio of voltage at the spaced points 32 and 33. This condition indicates that, with the new adjustment of the impedance-matching section P₄, complete compensation of the reactive component or phase angle of load impedance 10 is effected.

Unicontrol 65 may now be operated closing switch 52. Motor 55 is then rotated under the control of diodes 40 and 42 to adjust condenser 35 and establish unity ratio of voltage at the spaced points 30 and 31 along the line. When the desired unity ratio of voltage is reached, the magnitude of the load impedance 10 is compensated by the new adjustment of the impedance-matching section, and motor 55 is interrupted.

The adjustment of condenser 35 of the impedance-matching section required to compensate for the magnitude of the load impedance 10 may upset the compensation of phase angle. Likewise, an adjustment of condenser 36 to correct phase angle may cause a particular setting of condenser 35 to provide incomplete compensation for the magnitude of load impedance 10. For this reason, switches 52 and 52' are alternately opened and closed through unicontrol 65 until a complete compensation of magnitude and phase angle of the load impedance 10 is obtained.

One particular advantage of the described arrangement results from the use of differential windings 53, 54 and 53', 54' since such arrangements effectively balance the output signals from the associated amplifiers and detectors. Thus, as the impedance-matching section P₄ is properly adjusted to provide unity ratio of voltage between any two of the selected points along the line, an exact balance is obtained in the differential network. Therefore, for this operating condition which is sought to be obtained, the control effect is independent of the law of rectification of the diodes.

The arrangement of the drawing has been considered with reference to variations in the impedance of load 10, assuming the operating wave length of the system to be constant. However, variations in the operating wave length also cause impedance mismatching and may be viewed as effective variations in the load impedance. The control system corrects for such variations in a manner similar to that described above. Further, the control system may, if desired, be coupled with adjustable tuning elements of the oscillation generator 11 to vary the operating wave length of the system and control the standing waves of current and voltage along the line.

The described arrangement may, if desired, be utilized as an impedance-measuring system for ascertaining the impedance characteristics of the load 10. From the foregoing material it is apparent that the adjustable shunt condensers 35 and 36 of the impedance-matching network P₄ have particular values to match a load 10 of particular impedance to the line at a given operating wave length. Variations in magnitude or phase angle of the load impedance necessitate different adjustments of condensers 35 and 36. Therefore, a chart of the type utilized in the above-discussed prior impedance-measuring systems may be prepared to translate particular settings of adjustable elements 35 and 36 into impedance characteristics of the load. To this end, certain contour

lines of the chart may designate the values of the adjustable condensers 35 and 36 and the cooperating contour lines may represent the magnitude and phase angle of the load impedance. Where this use is made of the described arrangement, impedance measurements may be accomplished without the necessity of making computations from observed values of the standing waves on the transmission line.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A wave-translating arrangement comprising, a guide for electromagnetic waves effective to establish current and voltage conditions along its length in accordance with its operating wave length and the magnitude and phase angle of a load impedance connected to said guide at a predetermined point, a first pair of pickup devices coupled to said guide for developing a first control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with respect to said predetermined point that said first control effect varies with the effective magnitude of said load impedance, a second pair of pickup devices including at least one device in addition to said first pair and coupled to said guide for developing a second control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with respect to said predetermined point that said second control effect varies with the effective phase angle of said load impedance, and means for utilizing said first and second control effects so to vary the effective magnitude and phase angle of said load impedance that said ratios approach predetermined values.

2. A wave-translating arrangement comprising, a guide for electromagnetic waves effective to establish current and voltage conditions along its length in accordance with its operating wave length and the magnitude and phase angle of a load impedance connected to said guide at a predetermined point, a first pair of pickup devices coupled to said guide for developing a first control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with respect to said predetermined point that said first control effect varies with the effective magnitude of said load impedance, a second pair of pickup devices including at least one device in addition to said first pair and coupled to said guide for developing a second control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with respect to said predetermined point that said second control effect varies with the effective phase angle of said load impedance, and means for utilizing said first and second control effects so to vary the effective magnitude and phase angle of said load impedance that said ratios approach unity.

3. A wave-translating arrangement comprising, a guide for electromagnetic waves effective to establish current and voltage conditions along

its length in accordance with its operating wave length and the magnitude and phase angle of a load impedance connected to said guide at a predetermined point, a first pair of pickup devices coupled to said guide for developing a first control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with respect to said predetermined point that said first control effect varies with variations in said magnitude of said load impedance, a second pair of pickup devices including at least one device in addition to said first pair and coupled to said guide for developing a second control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with respect to said predetermined point that said second control effect varies with variations in said phase angle of said load impedance, and means for utilizing said first and second control effects to compensate at least in part said magnitude and phase angle of said load impedance so that said ratios approach predetermined values.

4. A wave-translating arrangement comprising, a simulated transmission line effective to establish current and voltage conditions along its length in accordance with its operating wave length and the magnitude and phase angle of a load impedance connected to said line at a predetermined point, a first pair of pickup devices coupled to said line for developing a first control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said line with respect to said predetermined point that said first control effect varies with the effective magnitude of said load impedance, a second pair of pickup devices including at least one device in addition to said first pair and coupled to said line for developing a second control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said line with respect to said predetermined point that said second control effect varies with the effective phase angle of said load impedance, and means for utilizing said first and second control effects so to vary the effective magnitude and phase angle of said load impedance that said ratios approach predetermined values.

5. A wave-translating arrangement comprising, a guide for electromagnetic waves effective to establish current and voltage conditions along its length in accordance with its operating wave length and the magnitude and phase angle of a load impedance connected to said guide at a predetermined point, a first pair of pickup devices coupled to said guide for developing a first control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with respect to said predetermined point that said first control effect varies with the effective magnitude of said load impedance, an additional pair of pickup devices coupled to said guide for developing a second control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with respect to said predetermined point that said second control effect varies with the effective phase angle of said load impedance, and means for utilizing said first and second control effects so to vary the effective magnitude and phase angle of said load imped-

ance that said ratios approach predetermined values.

6. A wave-translating arrangement comprising, a guide for electromagnetic waves effective to establish current and voltage conditions along its length in accordance with its operating wave length and the magnitude and phase angle of a load impedance connected to said guide at a predetermined point, a first pair of pickup devices coupled to said guide for developing a first control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with respect to said predetermined point that said first control effect varies in opposite senses with deviations of magnitude of said load impedance in opposite directions from a reference value, a second pair of pickup devices including at least one device in addition to said first pair and coupled to said guide for developing a second control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with respect to said predetermined point that said second control effect varies in opposite senses with deviations of phase angle of said load impedance in opposite directions from a reference value, and means for utilizing said first and second control effects so to vary the effective magnitude and phase angle of said load impedance that said ratios approach predetermined values.

7. A wave-translating arrangement comprising, a guide for electromagnetic waves effective to establish current and voltage conditions along its length in accordance with its operating wave length and the magnitude and phase angle of a load impedance connected to said guide at a predetermined point, a first pair of pickup devices coupled to said guide for developing a first control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points having a separation approximately equal to one-quarter of said wave length and so spaced along said guide with respect to said predetermined point that said first control effect varies in opposite senses with deviations of magnitude of said load impedance in opposite directions from a reference value, an additional pair of pickup devices coupled to said guide for developing a second control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points having a separation approximately equal to one-quarter of said wave length and so spaced along said guide with respect to said predetermined point that said second control effect varies in opposite senses with deviations of phase angle of said load impedance in opposite directions from a reference value, and means for utilizing said first and second control effects so to vary the effective magnitude and phase angle of said load impedance that said ratios approach predetermined values.

8. A wave-translating arrangement comprising, a guide for electromagnetic waves effective to establish current and voltage conditions along its length in accordance with its operating wave length and the magnitude and phase angle of a load impedance connected to said guide at a predetermined point, a first pair of pickup devices coupled to said guide for developing a first control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points having a separation

tion approximately equal to one-quarter of said wave length and so spaced along said guide with respect to said predetermined point that said first control effect varies in opposite senses with deviations of magnitude of said load impedance in opposite directions from a reference value, an additional pair of pickup devices coupled to said guide for developing a second control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points having a spacing of one-eighth of said wave length from said first-mentioned two selected points respectively so that said second control effect varies in opposite senses with deviations of phase angle of said load impedance in opposite directions from a reference value, and means for utilizing said first and second control effects so to vary the effective magnitude and phase angle of said load impedance that said ratios approach predetermined values.

9. A wave-translating arrangement comprising, a guide for electromagnetic waves having a characteristic impedance of a predetermined value and effective to establish current and voltage conditions along its length in accordance with its operating wave length and the magnitude and phase angle of a load impedance connected to said guide at a predetermined point, a first pair of pickup devices coupled to said guide for developing a first control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with respect to said predetermined point that said first control effect varies in opposite senses with deviations of the magnitude of said load impedance in opposite directions from said predetermined value, a second pair of pickup devices including at least one device in addition to said first pair and coupled to said guide for developing a second control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with respect to said predetermined point that said second control effect varies in opposite senses with deviations of the phase angle of said load impedance in opposite directions from zero electrical degrees, and means for utilizing said first and second control effects so to vary the effective magnitude and phase angle of said load impedance that said ratios approach predetermined values.

10. A wave-translating arrangement comprising, a guide for electromagnetic waves effective to establish current and voltage conditions along its length in accordance with its operating wave length and the characteristics of a load impedance connected to said guide at a predetermined point, an impedance-matching section including a first and a second adjustable element for compensating a first and a second characteristic respectively of said load impedance, a first pair of pickup devices coupled to said guide for developing a first control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with reference to said predetermined point that said first control effect varies with variations in said first characteristic of said load impedance, a second pair of pickup devices including at least one device in addition to said first pair and coupled to said guide for developing a second control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced

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along said guide with reference to said predetermined point that said second control effect varies with variations in said second characteristic of said load impedance, and means for utilizing said first and second control effects to adjust said first and second elements respectively of said impedance-matching section to compensate at least in part said characteristics of said load impedance so that said ratios of current and voltage approach predetermined values.

11. A wave-translating arrangement comprising, a simulated transmission line effective to establish current and voltage conditions along its length in accordance with its operating wave length and the characteristics of a load impedance connected to said guide at a predetermined point, a π -type impedance-matching section including a first and a second adjustable shunt element for compensating a first and a second characteristic respectively of said load impedance, a first pair of pickup devices coupled to said guide for developing a first control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with reference to said predetermined point that said first control effect varies with variations in said first characteristic of said load impedance, a second pair of pickup devices including at least one device in addition to said first pair and coupled to said guide for developing a second control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with reference to said predetermined point that said second control effect varies with variations in said second characteristic of said load impedance, and means for utilizing said first and second control effects to adjust said first and second elements respectively of said impedance-matching section to compensate at least in part said characteristics of said load impedance so that said ratios of current and voltage approach predetermined values.

12. A wave-translating arrangement comprising, a guide for electromagnetic waves effective to establish current and voltage conditions along its length in accordance with its operating wave length and the characteristics of a load impedance connected to said guide at a predetermined point, an impedance-matching section including a first and a second adjustable element for compensating a first and a second characteristic respectively of said load impedance, a first pair of pickup devices coupled to said guide for developing a first control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with reference to said predetermined point that said first control effect varies in opposite senses with deviations of said first characteristic of said load impedance in opposite directions from a reference value, a second pair of pickup devices including at least one device in addition to said first pair and coupled to said guide for developing a second control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with reference to said predetermined point that said second control effect varies in opposite senses with deviations of said second characteristic of said load impedance in opposite directions from a reference value, and a pair of reversible motors responsive to said first and second

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control effects for adjusting said first and second elements respectively of said impedance-matching section to compensate at least in part said characteristics of said load impedance so that said ratios of current and voltage approach predetermined values.

13. A wave-translating arrangement comprising, a guide for electromagnetic waves effective to establish current and voltage conditions along its length in accordance with its operating wave length and the characteristics of a load impedance connected to said guide at a predetermined point, an impedance-matching section including a first and a second adjustable element for compensating a first and a second characteristic respectively of said load impedance, a first pair of pickup devices coupled to said guide for developing a first control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with reference to said predetermined point that said first control effect varies in opposite senses with deviations of said first characteristic of said load impedance in opposite directions from a reference value, a second pair of pickup devices including at least one device in addition to said first pair and coupled to said guide for developing a second control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with reference to said predetermined point that said second control effect varies in opposite senses with deviations of said second characteristic of said load impedance in opposite directions from a reference value, a pair of reversible motors responsive to said first and second control effects for adjusting said first and second elements respectively of said impedance-matching section to compensate at least in part said characteristics of said load impedance so that said ratios of current and voltage approach predetermined values, and switching means for alternately rendering said motors responsive to said first and second control effects so that said first and second elements of said impedance-matching section are adjusted in alternation.

14. A wave-translating arrangement comprising, a guide for electromagnetic waves effective to establish current and voltage conditions along its length in accordance with its operating wave length and the characteristics of a load impedance connected to said guide at a predetermined point, an impedance-matching section for connecting said load impedance to said predetermined point in said guide and including a first and a second adjustable element for compensating a first and a second characteristic respectively of said load impedance, a first pair of pickup devices coupled to said guide for developing a first control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with reference to said predetermined point that said first control effect varies with variations in said first characteristic of said load impedance, a second pair of pickup devices including at least one device in addition to said first pair and coupled to said guide for developing a second control effect determined by the ratio of predetermined ones of said current and voltage conditions at two selected points so spaced along said guide with reference to said predetermined point that said second control effect varies with variations in said second characteristic of said load imped-

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ance, and means for utilizing said first and second control effects to adjust said first and second elements respectively of said impedance-matching section to compensate at least in part said characteristics of said load impedance so that said ratios of current and voltage approach predetermined values.

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