cold and weariness as daily companions and parries their attack, yet strangely loves them. When night descends he builds his fire and sits beside that focal point of life, and talks and sings with those who share this world.

Our paths crossed frequently over the next two years. Betty and I organized a burro trip of our own the following year and worried that Russell might not get back from New York in time to go with us, as we were depending on his strength and mountaineering skill. He just made it. We went on other Sierra Club trips and on American Youth Hostel bicycle trips, and we introduced Russell to cross-country skiing. When publicity about the klystron appeared in the newspapers, we were all surprised; we had no idea our friend from Palo Alto was such a celebrity. He explained how the klystron worked, in simple terms that we nonscientists could understand. We knew all about Sig and Bill, even though we never met them, and we followed Russell's accounts of their accomplishments with much interest. I remember the day in August 1940, when diffidently, but with obvious pride, he showed me their first royalty check for about $45, probably covering the royalty on the first 40-cm. tubes sold to the CAA for the blind-landing system.

Just before he left for Long Island in December, he came up to Berkeley for a final visit. He said that he would be back as soon as he could because he and Sig had no desire to work for Sperry or any other large industrial concern. As soon as the war was over, they planned to establish their own laboratory, probably near Stanford. It was to be nearly six years before he returned to make plans for that laboratory.

Patent Abstracts

For this Special Issue, instead of the usual abstracts of current patents, the Patent Abstracts section consists of figures, excerpts, and the first claim from patents which date from 1898 to as recent as 1970. These patents were suggested by authors from this Special Issue and other members of the microwave community for their probable historical interest to our readers. They represent but a sample of the many interesting and deserving patents which could have been included if space were unlimited.

Larger portions of the older patents have been included. They reveal the surprisingly keen insight and understanding of these early inventors in areas which are common to many of us today. I hope you will find these excerpts interesting and worthwhile. Complete copies of these older patents and many others of interest are still available in patent libraries, or from the U.S. Patent and Trademark Office, Box 9, Washington, DC 20231.

I apologize to the authors of patents which should have been included but were not, and I thank those who offered suggestions to aid in selecting the ones which were included.

N. R. DIETRICH
Associate Editor

613,809 Nov. 8, 1898

Method of and Apparatus for Controlling Mechanism of Moving Vessels or Vehicles

Inventor: N. Tesla.
Filed: July 1, 1898.

Abstract—To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at New York, in the county and State of New York, have invented certain new and useful improvements in methods of and apparatus for controlling from a distance the operation of the propelling-engines, the steering apparatus, and other mechanism carried by moving bodies or floating vessels, of which the following is a specification, reference being had to the drawings accompanying and forming part of the same.

The problem for which the invention forming the subject of my present application affords a complete and practicable solution is that of controlling from a given point the operation of the propelling-engines, the steering apparatus, and other mechanism carried by a moving object, such as a boat or any floating vessel, whereby the movements and course of such body or vessel may be directed and controlled from a distance and any device carried by the same brought into action at any desired time. So far as I am aware the only attempts to solve this problem which have heretofore met with any measure of success have been made in connection with a certain class of vessels the machinery of which was governed by electric currents conveyed to the controlling apparatus through a flexible conductor; but this system is subject to such obvious limitations as are imposed by the length, weight, and strength of the conductor which can be practically used, by the difficulty of maintaining with

safety a high speed of the vessel or changing the direction of movement of the same with the desired rapidity, by the necessity for effecting the control from a point which is practically fixed, and by many well-understood drawbacks inseparably connected with such a system. The plan which I have perfected involves none of these objections, for I am enabled by the use of my invention to employ any means of propulsion, to impart to the moving body or vessel the highest possible speed, to control the operation of its machinery and to direct its movements from either a fixed point or from a body moving and changing its direction however rapidly, and to maintain this control over great distances without any artificial connections between the vessel and the apparatus governing its movements and without such restrictions as these must necessarily impose.

In a broad sense, then, my invention differs from all of those systems which provide for the control of the mechanism carried by a moving object and governing its motion in that I require no intermediate wires, cables, or other form of electrical or mechanical connection with the object save the natural media in space. I accomplish, nevertheless, similar results and in a much more practicable manner by producing waves, impulses, or radiations which are received through the earth, water, or atmosphere by suitable apparatus on the moving body and cause the desired actions so long as the body remains within the active region or effective range of such currents, waves, impulses, or radiations.

The many and difficult requirements of the object here contemplated, involving peculiar means for transmitting to a considerable distance an influence capable of causing in a positive and reliable manner these actions, necessitated the designing of devices and apparatus of a novel kind in order to utilize to the best advantage various facts or results, which, either through my own investigations or those of others, have been rendered practically available.

As to that part of my invention which involves the production of suitable waves or variations and the conveying of the same to a remote receiving apparatus capable of being operated or controlled by their influence, it may be carried out in various ways, which are at the present time more or less understood. For example, I may pass through a conducting-path, preferably inclosing a large area, a rapidly-varying current and by electromagnetic induction of the same affect a circuit carried by the moving body. In this case the action at a given distance will be the stronger the larger the area inclosed by the conductor and the greater the rate of change of the current. If the latter were generated in the ordinary ways, the rate of change, and consequently the distance at which the action would be practically available for the present purpose, would be very small; but by adopting such means as I have devised—that is, either by passing through the conducting-path currents of a specially-designed high-frequency alternator or, better, still, those of a strongly-charged condenser—a very high rate of change may be obtained and the effective range of the influence thus extended over a vast area, and by carefully adjusting the circuit on the moving body so as to be in exact electromagnetic synchronism with the primary disturbances this influence may be utilized at great distances

Another way to carry out my invention is to direct the currents or discharges of a high-frequency machine or condenser through a circuit one terminal of which is connected directly or inductively with the ground and the other to a body, preferably of large surface and at an elevation. In this case if the circuit on the moving body be similarly arranged or connected differences of potential on the terminals of the circuit either by conduction or electrostatic induction are produced and the same object is attained. Again, to secure the best action the receiving-circuit should be adjusted so as to be in electromagnetic synchronism with the primary source, as before; but in this instance it will be understood by those skilled in the art that if the number of vibrations per unit of time be the same the circuit should now have a length of conductor only one-half of that used in the former case.

Still another way is to pass the currents simply through the ground by connecting both the terminals of the source of high-frequency currents to earth at different and remote points and to utilize the currents spreading through the ground for affecting a receiving-circuit properly placed and adjusted. Again, in this instance if only one of the terminals of the receiving-circuit be connected to the ground, the other terminal being insulated, the adjustment as to synchronism with the source will require that under otherwise equal conditions the length of wire be half of that which would be used if both the terminals be connected or, generally, if the circuit be in the form of a closed loop or coil. Obviously also in the latter case the relative position of the receiving and transmitting circuits is of importance, whereas if the circuit be of the former kind—that is, open—the relative position of the circuits is, as a rule, of little or no consequence.

Finally, I may avail myself, in carrying out my invention, of electrical oscillations which do not follow any particular conducting-path, but propagate in straight lines through space, of rays, waves, pulses, or disturbances of any kind capable of bringing the mechanism of the moving body into action from a distance and at the will of the operator by their effect upon suitable controlling devices.

In the following detailed description I shall confine myself to an explanation of that method and apparatus only which I have found to be the most practical and effectual; but obviously my invention in its broad features is not limited to the special mode and appliances which I have devised and shall here describe.

In any event—that is to say, whichever of the above or similar plans I may adopt—and particularly when the influence exerted from a distance upon the receiving-circuit be too small to directly and reliably affect and actuate the controlling apparatus I employ auxiliary sensitive relays or, generally speaking, means capable of being brought into action by the feeblest influences in order to effect the control of the movements of the distant body with the least possible expenditure of energy and at the greatest practicable distance, thus extending the range and usefulness of my invention.

A great variety of electrical and other devices more or less suitable for the purpose of detecting and utilizing feeble actions are now well known to scientific men and artisans and need not be all enumerated here. Confining myself merely to the electrical as the most practicable of such means and referring only to those which, while not the most sensitive, are perhaps more readily available from the more general knowledge which exists regarding them, I may state that a contrivance may be used which has long been known and used as a lightning-arrester in connection with telephone-switchboards for operating annunciators and like devices, comprising a battery the poles of which are connected to two conducting-terminals separated by a minute thickness of dielectric. The electromotive force of the battery should be such as to strain the thin dielectric layer very nearly to the point of breaking down in order to increase the sensitiveness. When an electrical disturbance reaches a circuit so arranged and adjusted, additional strain is put upon the insulating-film, which gives way and allows the passage of a current which can be utilized to operate any form of circuit-controlling apparatus.

Again, another contrivance capable of being utilized in detecting feeble electrical effects consists of two conducting plates or terminals which have, preferably, wires of some length attached to them and are bridged by a mass of minute particles of metal or other conducting material. Normally these particles lying loose do not connect the metal plates; but under the influence of an electrical disturbance produced at a distance, evidently owing to electrostatic attraction, they are pressed firmly against each other, thus establishing a good electrical connection between the two terminals. This change of state may be made use of in a number of ways for the above purpose.

Still another modified device, which may be said to embody the features of both the former, is obtained by connecting the two conducting plates or terminals above referred to permanently with the poles of a battery which should be of very constant electromotive force. In this arrangement a distant electrical disturbance produces a twofold effect on the conducting particles and insulating-films between them. The former are brought nearer to each other in consequence, of the sudden increase of electrostatic atttracion, and the latter, owing to this, as well as by being reduced in thickness or in number, are subjected to a much greater strain, which they are unable to withstand.

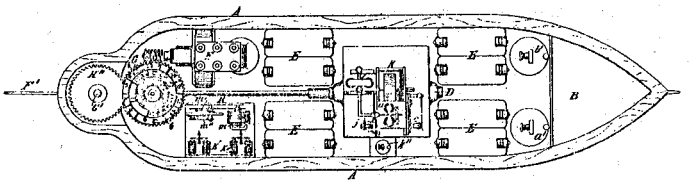
It will be obviously noted from the preceding that whichever of these or similar contrivances be used the sensitiveness and, what is often still more important, the reliability of operation is very materially increased by a close adjustment of the periods of vibration of the transmitting and receiving circuits, and although such adjustment is in many cases unnecessary for the successful carrying out of my invention, I nevertheless make it a rule to bestow upon this feature the greatest possible care, not only because of the above-mentioned advantages, which are secured by the observance of the most favorable conditions in this respect, but also and chiefly with the object of preventing the receiving-circuit from being affected by waves or disturbances emanating from sources not under the control of the operator. The narrower the range of vibrations which are still capable of perceptibly affecting the receiving-circuit the safer will the latter be against extraneous disturbances. To secure the best result, it is necessary, as is well known to experts, to construct the receiving circuit or that part of the same in which the vibration chiefly occurs so that it will have the highest possible self-induction and at the same time the least possible resistance. In this manner I have demonstrated the practicability of providing a great number of such receiving-circuits—fifty or a hundred, or more—each of which may be called up or brought into action whenever desired without the others being interfered with. This result makes it possible for one operator to direct simultaneously the movements of a number of bodies as well as to control the action of a number of devices located on the same body, each of which may have a distinct duty to fulfil. In the following description, however, I shall show a still further development in this direction—namely, how, by making use of merely one receiving-circuit, a great variety of devices may be actuated and any number of different functions performed at the will and command of the distant operator.

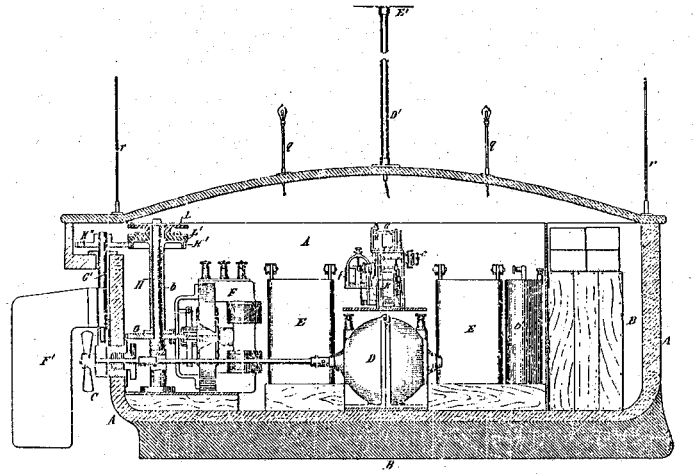
It should be stated in advance in regard to the sensitive devices above mentioned, which may be broadly considered as belonging to one class, inasmuch as the operation of all of them involves the breaking down of a minute thickness of highly-strained dielectric, that it is necessary to make some provision for automatically restoring to the dielectric its original unimpaired insulating qualities in order to enable the device to be used in successive operations. This is usually accomplished by a gentle tapping or vibration of the electrodes or particles or continuous rotation of the same; but in long experience with many forms of these devices I have found that such procedures, while suitable in simple and comparatively unimportant operations, as ordinary signaling, when it is merely required that the succeeding effects produced in the receiving-circuit should differ in regard to their relative duration only, in which case it is of little or no consequence if some of the individual effects be altered or incomplete or even entirely missed, do not yield satisfactory results in many instances, when it may be very important that the effects produced should all be exactly such as desired and that none should fail. To illustrate, let it be supposed that an official directing the movements of a vessel in the manner described should find it necessary to bring into action a special device on the latter or to perform a particular operation, perhaps of vital moment, at an instant's notice and possibly when, by design or accident, the vessel itself or any mark indicating its presence is hidden from his view. In this instance a failure or defective action of any part of the apparatus might have disastrous consequences and such cases in which the sure and timely working of the

machinery is of paramount importance may often present themselves in practice, and this consideration has impressed me with the necessity of doing away with the defects in the present devices and procedures and of producing an apparatus which while being sensitive will also be most reliable and positive in its action. In the arrangement hereinafter described these defects are overcome in a most satisfactory manner, enabling thousands of successive operations, in all respects alike, being performed by the controlling apparatus without a single irregularity or miss being recorded.

Having now described my invention, what I claim is—

1. The improvement in the art of controlling the movements and operation of a vessel or vehicle herein described, which consists in producing waves or disturbances which are conveyed to the vessel by the natural media, actuating thereby suitable apparatus on the vessel and effecting the control of the propelling-engine, the steering and other mechanism by the operation of the said apparatus, as set forth.





2,041,378 May 19, 1936

High-Frequency Transmission System

Inventor: P. H. Smith.
Assignee: Bell Telephone Laboratories, Inc.
Filed: Mar. 26, 1932.

Abstract—This invention relates to transmission systems and especially to methods and means for preventing wave reflection in high frequency transmission systems.

In high frequency transmission systems wave reflection which produces line losses and undesired radiation is usually suppressed, in the case of open-ended lines, by terminating the line in a pure resistance equal to the line surge impedance and, in the case of lines terminated for certain reasons in impedances having a value different from that of the surge impedance of the associated line, by employing lumped or distributed impedance transformers, or suppressors comprising series and shunt reactances, which function to match the load to the line. The transformers and suppressors in use at present aside from being comparatively costly, do not in general accomplish the desired result in an entirely satisfactory manner.

It is one object of this invention to improve the operation of transmission lines in a simple and economical manner.

It is another object of this invention to suppress standing waves on transmission lines in a more effective manner than heretofore achieved and with minimum dissipation losses.

It is a further object of this invention to suppress standing waves on transmission lines produced by auxiliary line apparatus such as switches, insulators and the like.

It is still another object of this invention to suppress standing waves on transmission lines comprising sections having different surge impedances.

According to this invention, standing waves are suppressed on a line connected between a source of high frequency energy and a load having an impedance value substantially different from the line surge impedance by means of a reactance, preferably a distributed reactance in the form of an auxiliary line, connected across the line and critically positioned with respect to a point of maximum standing wave current. The distance between the maximum point and the position of the reactance is not greater than one-eighth of a wave length and is mathematically related to the reactance value, which in auxiliary line reactances corresponds to the length of line, to the ratio of the maximum and minimum current values and to the line surge impedance. For a given ratio and line surge impedance there are two particular values of reactance each corresponding to one particular reactance position with respect to a given maximum current point.

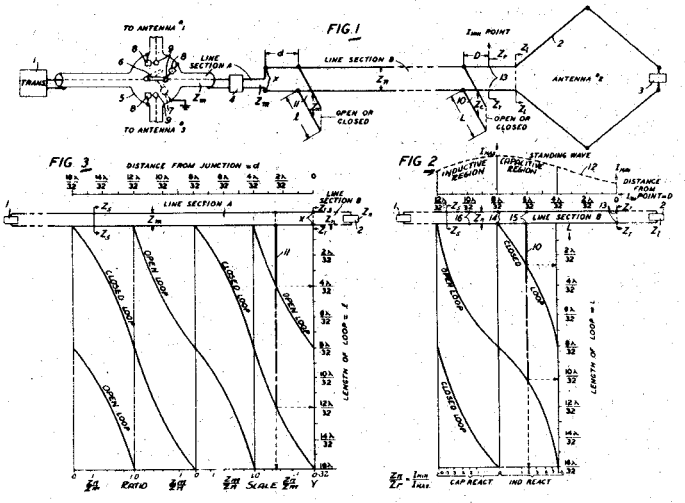
On lines comprising, for example, two sections having different surge impedances standing waves are suppressed on the section adjacent to the load according to the manner explained above and on the other section by means of a reactance also preferably of the auxiliary line type, the reactive value of which is mathematically related to its position with respect to the junction point of the sections and to the ratio of their surge impedances. The reactance may be connected across either section. For given values of surge impedances there are two particular values of reactance each corresponding to a particular position on each section.

Waves produced on transmission lines by the undesired impedance effects of switches and other auxiliary apparatus are suppressed by means of adjustable impedances, one of which is connected electrically to the line at each position of auxiliary apparatus and adjusted to transform the undesired impedance into the characteristic impedance of the line.

What is claimed is:

1. A method of preventing standing waves on a portion of a transmission line connected between a source of energy and a load utilizing a substantially pure reactance which comprises determining the ratio of the maximum and minimum standing wave amplitudes, ascertaining a current maximum point on said line and connecting a pure reactance having a value dependent upon said ratio across the line at a point located at a distance from the ascertained current maximum point dependent upon said ratio and less than an eighth of a wave length.

15 Claims



2,129,711 Sept. 13, 1938

Guided Transmission of Ultra-High-Frequency Waves

Inventor: G. C. Southworth
Assignee: American Telephone and Telegraph Company.
Filed: Mar. 16, 1933.

Abstract—An object of my invention is to provide a new and improved system for the transmission of electrical effects from one place to another place at a distance therefrom by means of electromagnetic waves associated with a dielectric guide extending between the two places. Another object of my invention is to provide for signaling along such a guide by means of such waves. Another object is to provide for the generation of high frequency electric conduction currents in a suitable medium and the application of their energy to generate corresponding "displacement" current waves for transmission along a guide of dielectric material. An object complementary to the

foregoing is to provide for the translation of the energy of received displacement currents in a dielectric guide into conduction currents in a dielectric guide into conduction currents in associated receiving apparatus. Still another object is to provide suitable apparatus and a proper method so that electric waves may be transmitted along a dielectric guide without excessive dissipation of their energy in the guide or in the medium adjacent thereto. In some examples of my invention the guide employed may be partly dielectric and partly conductive.

All these objects and various other objects and advantages of my invention will become apparent on consideration of a limited number of examples of practice in accordance with the invention which I have chosen for presentation in this specification. It will be understood that the following disclosure relates principally to these particular examples of the practice of the invention and certain scientific principles involves in such practice, and that the scope of the invention will be indicated in the appended claims.

What is claimed is:

1. The method of transmitting electromagnetic effects which comprises applying electromagnetic waves to a dielectric guide and propagating these waves along said guide with the energy flow largely in the one direction of propagation and deriving the power available within the guide at some other point along the guide, the propagation being characterized by a critical existence relation between the frequency of said waves, a transverse dimension of said guide and the index of refraction of the dielectric medium comprising said guide.

70 Claims

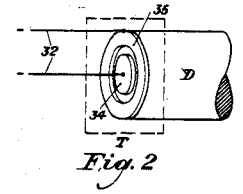


Fig. 2

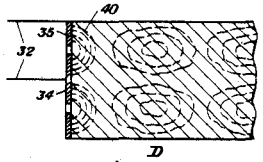


Fig. 3

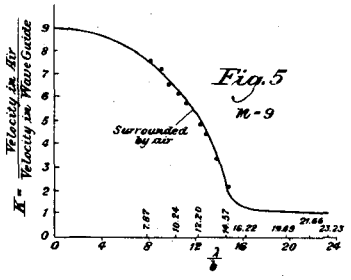


Fig. 5
M-9

2,106,769 Feb. 1, 1938

Transmission of Guided Waves

Inventor: G. C. Southworth.
Assignee: American Telephone and Telegraph Company.
Filed: Aug. 23, 1935.

Abstract—A principal object of my invention is to provide new and improved apparatus and a corresponding method for matching impedances in the operation of dielectric guides. Another object of my invention is to provide for transmitting electromagnetic waves over dielectric guides and associated apparatus with impedance match at transition places. Another object is to provide a chamber with an input and output, the end walls of the chamber and the places of application of the input and output being relatively adjustable along the length of the chamber to secure an impedance match between the input and the output. All these objects and other objects and advantages of my invention will become apparent on consideration of a limited number of examples of practice in accordance with the invention which I have chosen for presentation in the following specification. It will be understood that this specification relates principally to these particular embodiments of the invention and that the scope of the invention will be indicated in the appended claims.

In my pending application, supra, and also in my pending applications Serial No. 661,154 filed March 16, 1933 and Serial No. 701,711 filed December 9, 1933 are disclosed systems for the guided transmission of electromagnetic waves of guide transmission of electromagnetic waves of unusual character. The wave guiding structure may take a variety of forms; typical is a guide consisting of a rod of dielectric material having a high dielectric coefficient relative to unity. Another typical guide comprises a metallic pipe, containing only a dielectric medium, such as air, for specific example. In these typical dielectric guides, as in all the others disclosed, there is a dielectric medium and an enclosing boundary which defines a discontinuity in electromagnetic properties and within which electromagnetic waves may be propagated.

A specific dielectric guide which may be considered is a cylinder of ceramic material having rutile (titanium dioxide) as its principal constituent. This prepared material may be made to have a dielectric constant of about 70 to 90, and a low dielectric loss factor, and it has the favorable property that its loss factor decreases with increasing frequency. The specific gravity is about 4 and its bending strength and other physical properties are favorable for practical use in dielectric guides. For this purpose a cylinder of this ceramic material may or may not have a metallic sheath.

Aside from the structure of the guide, the systems disclosed in my pending applications, supra, are unique in respect of the character of the wave transmission. The field pattern of the waves transmitted through a dielectric guide may take a great variety of forms, but in each instance thus far observed all forms have certain characteristics in common. Thus, it has been shown that for each form the dielectric guide presents the attenuation characteristic of a high-pass filter. The critical or cut-off frequency is dependent on the transverse dimensions of the guide and the index of refraction of the dielectric medium comprising it, and it may be more or less distinct depending on the resistivity of the metallic portions of the guide and other factors that may influence energy dissipation along the guide. The phase velocity, too, is dependent on the transverse dimensions of the guide, and it is ordinarily either greater or less than that characteristic of light in the dielectric medium, depending on whether there is or there is not a metallic sheath around the dielectric medium. The absence of the go-and-return flow of conduction current is another characteristic common to many dielectric guide systems.

The expression "dielectrically guide waves", as used in this specification, denotes the unique waves discussed hereinbefore and all other guided electromagnetic waves of equivalent character. "Dielectric guide" denotes a wave guide adapted for the transmission of dielectrically guide waves.

I claim:

1. A metal sheathed wave guide, a source of electromagnetic waves, a metallic-walled chamber enclosing said source and connected with said guide to establish dielectrically guide waves therein, the impedance of said guide being matched with the impedance presented by said source.

21 Claims

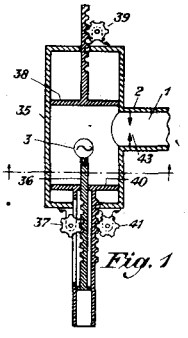


Fig. 1

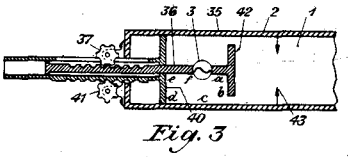


Fig. 3

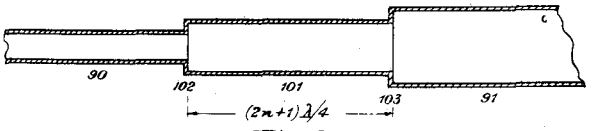


Fig. 6

2,527,146 Oct. 24, 1950

Broad-Band Coaxial Line to Wave Guide Coupler

Inventor: W. W. Mumford.
Assignee: Bell Telephone Laboratories, Inc.
Field: Mar. 27, 1945.

Abstract—This invention relates to transmission coupling apparatus, and particularly to a coaxial line-to-wave guide transducer for use in a multi-frequency microwave signaling system.

Heretofore in microwave signal systems, a tuner of the piston type has been

embodied in a wave guide for matching the impedance of the wave guide and that of the coaxial conductor line connected therewith. Such piston tuning tends to provide the system substantially with a single frequency versus impedance characteristic. In other words, the frequency versus impedance characteristic of the coaxial-to-wave guide coupling tends to peak sharply at a particular operating frequency. Hence, reflection effects tend to be introduced in the signal system as the operating frequency varies from the particular frequency. This requires, at least, tuning the system for each different operating frequency. One way proposed heretofore to overcome such single frequency characteristic has been to extend the bare inner conductor of the coaxial conductor line entirely across the interior of the wave guide so that the free end of the inner conductor projects outside the wave guide. This tends to provide the coaxial-to-wave guide coupling with a frequency versus impedance characteristic which was substantially flat over a limited band width.

The present invention contemplates a coaxial line-to-wave guide transducer provided with a frequency versus impedance characteristic which is substantially flat over a wider band width than any obtained heretofore.

The main object of the invention is to match the impedance of a coaxial conductor line and a wave guide over a broad band of signal frequencies.

Another object is substantially to eliminate reflection effects over a broad band of signal frequencies.

In a specific embodiment of the present invention which is disclosed in connection with a conventional microwave signaling system described hereinafter, the inner conductor of the coaxial line and the insulation thereon are extended substantially one-fifth wavelength in the interior of the wave guide, each end wall of the wave guide has its inner surface located substantially one-fifth guide-wavelength from the vertical axis of the inner conductor positioned in proximity of each end wall, and a vertical plane embodying a vertical axis of the inner conductor is spaced from a vertical plane including the longitudinal axis of the wave guide. It has been found in practice that this coaxial-to-wave guide coupling is provided with a substantially flat frequency versus impedance characteristic for a ± 9 per cent band at a frequency of the order of 3,000 mega cycles.

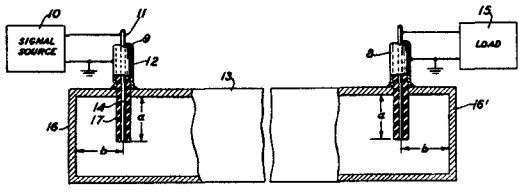
In an alternative embodiment of the invention, the inner conductor and the insulation thereon are extended substantially one-fifth wavelength into the interior of the wave guide, each end wall of the wave guide has its inner surface located substantially one-quarter wavelength from the vertical axis of the inner conductor positioned in proximity thereof, and a vertical plane embodying the vertical axis of the inner conductor coincides with a vertical plane including the longitudinal axis of the wave guide. It has been found in practice that this coaxial-to-wave guide coupling exhibits a substantially flat frequency versus impedance characteristic for a ± 12 per cent band at a frequency of the order of 3,000 megacycles.

In both foregoing embodiments of the invention, a tuning plug is, or may be provided, movably mounted in one wall of the wave guide in axial alignment with the dielectric-covered inner conductor. A further embodiment of the invention concerns the extension of the insulation-covered inner conductor entirely across the interior of the wave guide, and the mounting of a tubular tuning plug in a movable manner in a wall of the wave guide in proximity of the free end of the insulation-covered inner conductor and in coaxial relation therewith. Such tuning plugs provide a variable capacity effect which tends to nullify any inductive effect inherent in the insulation-covered inner conductor and in coaxial relation therewith. Such tuning plugs provide a variable capacity effect which tends to nullify any inductive effect inherent in the insulation-covered inner conductors and thereby further tends to widen the frequency versus impedance characteristics of the coaxial-to-wave guide coupling.

What is claimed is:

1. In combination, a wave guide, and a coaxial line having its outer conductor connected to said guide and its inner conductor extending into the interior of said guide through an opening in one side wall thereof, said inner conductor being imbedded in a solid dielectric substantially throughout its entire length in the interior of said guide, and said inner conductor being positioned off the longitudinal axis of said guide.

12 Claims



2,606,974 Aug. 12, 1952

Directional Coupler

Inventor: H. A. Wheeler.
Assignee: Hazeltine Research, Inc.
Filed: May 16, 1946.

Abstract—The present invention relates to systems for translating wave signals of various wave lengths and, particularly, to such systems utilizing wave guides such as transmission lines by which to select between wave signals traveling in opposite directions in the same path of propagation.

Wave guides are widely used to guide the propagation of wave-signal energy along a restricted path between two spaced points such, for example, as between a wave-signal transmitter and its associated wave-signal antenna system or between a receiving antenna system and a wave-signal receiver. The term "wave guide" as used in the present specification and claims applies to a system of longitudinal conductive surfaces which act as the lateral boundary of an electric wave and have the ability of directing the propagation of such waves, much as the rigid wall of a speaking tube is used to guide sound by preventing the sound from spreading into space. Wave guides may take the form of a pair of conductors in open space, such as a power line or a telephone line, or may comprise one conductor enclosed within but electrically insulated from a second conductor as in a conventional coaxial transmission line, or may simply comprise a single hollow conductor having such transverse dimensions as to render it capable of propagating an electric wave through the interior of the conductor.

It is usually desirable when using wave guides that the wave-signal energy shall flow along the wave guide only in one direction during a given operating condition of the wave-signal system since this gives rise to maximum efficiency and stability of the system operation. Any wave-signal energy flowing along the wave guide simultaneously in both forward and backward directions results in standing waves of potential and current along the wave guide. The presence of such standing waves thus is often indicative of impaired system efficiency and is conducive to undesirable instability of the system operation.

In certain applications of wave guides, however, standing waves are deliberately created along the wave guide to attain a particular result. Typical of such applications is the radio-frequency impedance-measuring system wherein an impedance-measuring system wherein an impedance of unknown value is coupled to the end of a wave guide of known characteristic impedance and the maximum and minimum values of any standing waves created along the wave guide are observed as measure of the magnitude and phase angle of the unknown impedance.

In all such applications of wave guides, it consequently is frequently desirable to provide an arrangement for indicating the presence of standing waves as an indication of an undesirable operating condition or for measuring the values of a standing wave as a measure of the unknown value of an impedance which gives rise to the standing wave. Additionally, it often is desirable that the actual value of wave-signal power supplied from a wave-signal source to a load device be easily and readily measured without regard to the presence or absence of standing waves along a wave guide which couples the source to the load device.

Measurements of the maximum and minimum amplitude values of a standing wave, commonly-referred to as a measurement of the "standing-wave ratio," and measurement of the power supplied to a load device have heretofore been accomplished by a so-called slotted wave guide." The slotted wave guide is a section of wave guide preferably longer than one-half wave length and having a longitudinal slot in the outer conductor thereof by which a capacitive-pickup probe or an inductive-pickup loop may be inserted into the electromagnetic field within the wave guide. This probe or loop is movable within the slot longitudinally along the wave guide and the maximum and minimum wave-signal potentials induced on the probe, or currents induced in the loop, are a measure of the existing standing-wave ratio. By proper calibration, the slotted wave-guide arrangement described may also measure the wave-signal power which is dissipated by a wave-signal power which is dissipated by a wave-signal load device. This prior standing-wave indicating arrangement, while it is extensively used in practice, is not as simple in construction or as convenient in operation as is desirable and is characterized by several well-known limitations and disadvantages.

In certain applications where wave guides are used for wave-signal propagation, it is desirable that the value of wave-signal energy flowing in one direction along the wave guide be selectively measured without the measurement being affected by any wave-signal energy flowing in the opposite direction. One prior arrangement for effecting such measurement includes a loop of wire inserted into the electromagnetic field of a wave guide of the coaxial transmission-line type to provide both magnetic and electric coupling with the inner conductor of the line. This loop within the transmission line is connected between a resistor and indicating circuit. By proper selection of the values of magnetic and electric couplings between the loop and the inner conductor of the line, and the value of the terminating resistor, the magnetic and electric couplings add together in the indicating circuit for a traveling wave of wave-signal energy propagating in one direction along the transmission line but cancel out for a traveling wave in the reverse direction. This arrangement has the important disadvantages that the magnitude of wave-signal energy coupled into the pickup loop decreases rapidly with increasing wave length, so that the arrange-

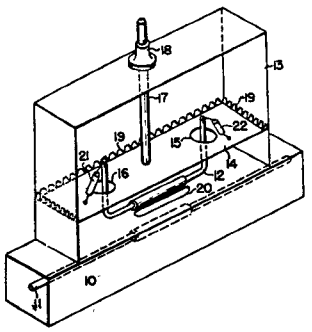
ment is highly frequency selective. This is caused by the loop being much shorter than one-quarter wave length so that the coupling is small at best, the coefficients of magnetic and electric couplings between the pickup loop and the adjacent length of transmission line being substantially less than unity. There is the additional disadvantage that proper operation of the arrangement necessitates a critical orientation of the pickup loop relative to the axis of the tranmission line by which to select the correct value of mutual inductive coupling. In general, the circuit configuration required to attain the desired operation is rather critical and cannot be computed in advance but can be established only by a careful adjustment through the process of trial and error.

It is an object of the present invention, therefore, to provide a new and improved system for translating wave signals and one which avoids one or more of the disadvantages and limitations of prior such systems of the type described.

What is claimed is:

1. A wave-signal translating system adapted to be positioned along a path of translation of wave signals having a substantially planar wave front comprising, a wave guide having its longitudinal axis substantially parallel to said path for translating wave signals along a second path with substantially the same velocity as that of said first path and including a longitudinally extending elongated aperture, said aperture having a length equal approximately to a quarter wave length at a selected wave length of said first-mentioned wave signals, and said wave guide including at least two conductors having approximately parallel substantially dissipationless conductor portions separated by a distance much less than their length and much less than the wave length of said wave signals, said paths adapted to have distributed magnetic and electric coupling therebetween through said aperture, and means for terminating said wave guide at one end thereof by an impedance having such value that substantially no wave-signal energy is developed at the other end of said wave guide in response to a pure traveling wave traveling through said parallel portions and in a direction corresponding to the direction from said one end to said other end of said wave guide.

11 Claims



2,706,782 Apr. 19, 1955

Broad-Band Microwave Noise Source

Inventor: W. W. Mumford.
Assignee: Bell Telephone Laboratories, Inc.
Filed: June 11, 1949.

Abstract—This invention relates to microwave transmission systems and more particularly to a broad-band microwave noise source therefor.

It is well known in the art that certain measurements of electrical transmission systems, for example, the noise figure or the gain of radio receiver and repeater circuits may be made most expeditiously by the use of standard noise generators. A noise generator suitable therefore must produce, among other factors, a dependable volume of noise energy substantially unaffected by ambient conditions, have an output frequency band width substantially larger than the band width of the device under test, and be capable of being impedance matched to the input of the device over the entire wide band of frequencies. In the short wave and ultra-short wave regions, devices such as thermal resistance noise sources and temperature limited diodes have been used, but these have not provided entirely satisfactory at microwave frequencies. The former involves prohibitively high temperatures at which the thermal source must operate in order to generate a sufficient volume of microwave noise for certain measurements and the latter suffers from the difficulty of obtaining a satisfactory impedance match over a wide band width at microwave frequencies.

It is therefore an object of the present invention to produce broad-band microwave noise energy.

Another object of the present invention is to produce such microwave noise energy substantially dependent of the generator operating current and ambient temperature variations.

It is a further object of the invention to produce broad-band microwave noise energy capable of being efficiently coupled to a microwave transmission system by maintaining a good impedance match between the noise source and said transmission system over substantially the entire broad frequency band.

In accordance with the invention, noise energy is derived from an electrical gas discharge and applied directly from the body of the discharge to a microwave transmission system.

In the simple embodiments of the invention to be hereinafter described in detail, microwave noise energy is generated by isolating microwave energy produced by the positive column of an electrical gas discharge which is developed laterally across a section of microwave guide between two electrodes located in tubular extensions of the wave-guide walls on either side of the wave-guide section.

In a first embodiment, the wave-guide section is sealed at one end across its cross-section by a metallic plunger and at the other end by a sheet of dielectric material. The resulting cavity is filled with the gaseous discharge medium. Microwave energy generated in the cavity by the positive column discharge is transmitted through the dielectric sheet to the connected transmission system. In another embodiment of the invention the discharge medium is confined in an elongated diode structure, for example, a commercial fluorescent lamp, extending laterally across the section through two holes in the wave-guide walls. The portions of the structure containing the electrodes project on each side beyond the walls and are enclosed in the tubular extensions.

What is claimed is:

1. A microwave noise generator comprising a waveguide section having a symmetrical cross-section, said wave-guide section having a pair of coaxially arranged and oppositely located openings each in a wall of said section, said openings having cross-sectional dimensions smaller than said wave-guide cross-section, tubular members of electrically conducting material having one end of each connected to one of said walls of said section around the periphery of said openings and extending perpendicularly away from said section, an electrode means located in each of said members, and means for maintaining an electrical arc discharge between said electrodes, said arc discharge having a positive column portion, the dimension of said wave-guide cross-section measured between said opposite openings being less than the length of said positive column portion.

6 Claims

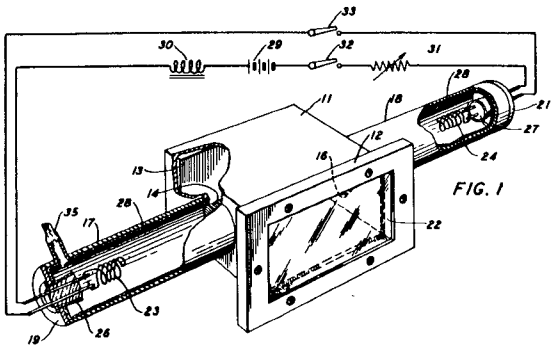


FIG. 1

2,899,652 Aug. 11, 1959

High-Frequency Negative Resistance Device

Inventor: W. T. Read, Jr.
Assignee: Bell Telephone Laboratories, Inc.
Filed: June 24, 1954.

Abstract—This invention relates to semiconductive translators and more particularly to negative dynamic resistance devices of the type disclosed in the application of W. Shockley, Serial No. 333, 449, filed January 27, 1953, now Patent No. 2,794,917.

In the aforenoted Shockley application a semiconductive structure is disclosed wherein at certain frequencies of applied voltage the current flowing therein is shifted in phase with respect to the voltage to an extent that power is delivered from a source of direct current to the alternating signal. This phase shift is realized by Shockley by a delay in the transit of charge through a portion of a semiconductive structure. Charge carriers, electrons, of a semiconductive structure. Charge carriers, electrons, or holes, i.e., electron deficits, were injected in these devices, for example from a forward biased *n-p* junction, and then flowed across a space charge region or a composite region consisting of a portion in which carrier flow is by diffusion and a space charge region.

The present invention is directed to semiconductive, transit-time, negative dynamic resistances of structural forms other than those disclosed by Shockely wherein charge carriers are injected into the region where the phase shift of current with respect to applied signal voltage is effected by the mechanism of electric field generation of hole-electron pairs.

An object of this invention is the realization of a negative dynamic resistance at frequencies of at least the decimeter range of wavelengths.

Another object of this invention is to localize the field generation of charge carriers in a space charge region of a semiconductive body.

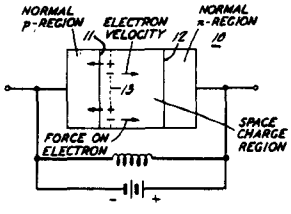
Another object of this invention is to fix the distance to the edges of the space charge region from the point of localized field generation.

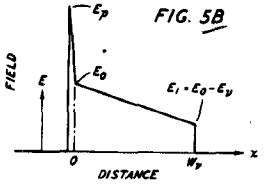
Other objects are to simplify the structure of semiconductive negative impedances and to facilitate their coupling to suitable circuits for the utilization of their characteristics.

What is claimed is:

1. A high frequency negative resistance comprising a body of semiconductive material having portions of opposite conductivity type, a conductivity transition layer intermediate said portions, means for applying a reverse bias to said body to produce a space charge region encompassing said transition layer and means for applying an alternating signal to said body, the magnitude of the combined bias and signal in the bias aiding direction being sufficient to produce a maximum field greater than about 100,000 $(E_g/0.7)^{3.2}$ volts per centimeter where E_g is the energy gap of the material at said layer in a localized portion of said space charge region, the transit time of the effective charge carriers from said layer to the edge of said space charge region being so correlated with the signal period that the integrated product of signal voltage and signal current is negative.

14 Claims





2,922,123 Jan. 19, 1960

Directional Filters for Stripline Transmission Systems

Inventor: S. B. Cohn.
Assignee: United States of America as Represented by the Secretary of the Army.
Filed: Feb. 26, 1957.

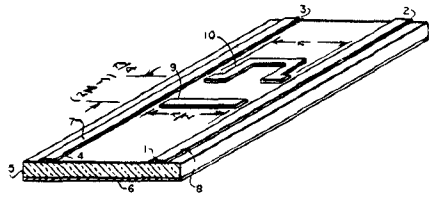
Abstract—The invention relates to directional filters, i.e., to filter components that have both the properties of selecting or extracting a signal having a certain band of frequencies from signals having other bands of frequencies and directing said signal into a predetermined circuit. It also relates to directional filter components designed for combining a signal of one band of frequencies with signals having other bands of frequencies and for directing the combined signals over a single circuit. More particularly, the invention relates to a directional filter component suitable for incorporation in a microwave strip-line transmission system to provide for multiplexing operations.

A strip-line transmission system is one designed for microwave transmission, and is composed of a conductor separated by a dielectric from a ground plane. The strip line transmission lines are used primarily in short line arrangements. They make take several configurations, one of which is a wire, supported a uniform distance from a conducting surface by dielectric beads spaced along the wire at regular intervals. Another configuration, and the one used in this application to disclose the invention, is a strip of conducting material supported upon one side of a sheet of dielectric material, the opposite side of which is covered with a conducting material. Still another configuration of a strip-line transmission system provides a strip of conducting material immersed within a dielectric material supported upon a conducting surface. Other configurations of strip-line transmission systems are possible and for further information concerning their nature and characteristics reference is made to Proceeding of I.R.E. No. 40, December 1952, page 1644 ff.

What is claimed is:

1. A strip-line directional filter component for a microwave multiplexing system comprising a sheet of dielectric material; a conductive coating affixed to a first side of said sheet of dielectric material; a pair of conductive strips affixed in spaced relation to a second side of said sheet of dielectric material, the pair of conductive strips and the conductive coating forming boundaries for an electromagnetic field therebetween and constituting two transmission lines along which microwave energy may be propagated; a first transverse conductive strip affixed to said second side of said sheet of dielectric material extending between said pair of conductive strips, said first transverse conductive strip and said conductive coating forming a first resonator and said first transverse conductive strip having a length to tune said first resonator to a predetermined frequency; a second transverse conductive strip affixed to said second side of said sheet of dielectric material extending between said pair of conductive strips, said second transverse conductive strip and said conductive coating forming a second resonator, the said second transverse conductive strip having a length equal to twice the length of the first transverse conductive strip whereby said second resonator will be tuned to the same frequency as the first resonator is tuned; and means coupling said first and second transverse conductive strips to each of said pair of conductive strips at points spaced apart along each of said pair of conductive strips a distance equal to one-quarter wave length at the frequency of said resonators.

2 Claims



3,091,743 May 28, 1963

Power Divider

Inventor: E. J. Wilkinson.
Assignee: Sylvania Electric Products, Inc.
Filed: Jan. 4, 1960.

Abstract—This invention relates generally to microwave apparatus, and is more particularly concerned with an improved power divider capable of distributing input radio frequency energy equally between any selected number of output loads.

Radio frequency power dividers have many applications, some of which impose more stringent operational characteristics than others. In the field of phased arrays, for example, it is desirable to divide an input signal into a plurality of equi-phase, equi-amplitude, non-interacting signal outputs, the number of outputs being odd or even in accordance with the requirements of a particular system.

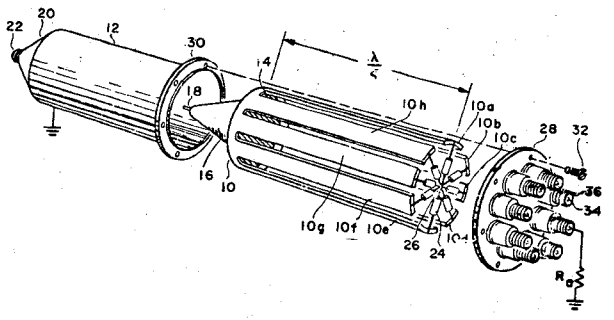
Briefly, the power divider in accordance with the invention consists of a coaxial transmission line structure having hollow cylindrical inner and outer conductors, the inner conductor of which is split into a plurality of equal length circumferentially spaced splines, the number of splines being equal to the desired number of output channels. All of the splines are shorted together at the input to accommodate a common input terminal, and at the output end, each of the splines is connected to a suitable terminating resistor. The terminating resistors are of identical value, one terminal of each of which is connected to an electrically neutral or common junction. A signal applied to the input terminal divides equally among the plurality of splines, each of which with the outer conductor functions as a transmission line, and the terminating resistors in conjunction with the splines prevent interaction of the output signals. The input impedance of the divider is matched to the characteristic impedance of each of the output transmission lines when the conditions for isolation are satisfied, and consequently does not introduce discontinuities in the system is which it is used.

What is claimed is:

1. A microwave power divider comprising, a plurality of two-conductor transmission lines each approximately a quarter-wavelength long at the frequency of operation and each having the same characteristic impedance, means connecting like conductors of said transmission lines together at one end thereof, means for coupling an input signal to said one end of said transmission lines, a like plurality of resistors each having a resistance equal to

the quotient of said characteristic impedance divided by the square root of the number of transmission lines, means connecting one terminal of said resistors to the other end of corresponding ones of said like conductors, means connecting the other terminals of said resistors together at an otherwise unconnected terminal, and a like plurality of output terminals connected to said other end of corresponding ones of said like conductors.

6 Claims



3,491,314 Jan. 20, 1970

Phase Shifter Having Means to Simultaneously Switch First and Second Reactive Means Between a State of Capacitive and Inductive Reactance

Inventor: J. F. White.
Assignee: Microwave Associates, Inc.
Filed: Apr. 29, 1965.

Abstract of the Disclosure

This application discloses electric wave phase shifters in which pairs of varactor diodes, spaced between 70° and 110° of electrical wavelength apart, are coupled across a transmission line in circuit with inductive means, in combination with biasing and switching means which switch the diodes between two conductive states. In one of these states a net capacitive disturbance is introduced, while in the other state a net inductive disturbance is introduced.

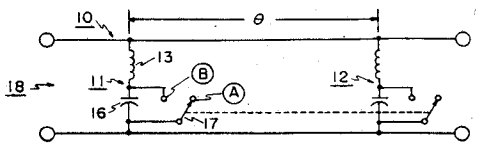
This invention relates to phase shifts and in particular to electromagnetic wave phase shifters capable of high power wide band operation.

While phase shifters have a multitude of uses, one of the most critical is in phased array antenna systems. Antenna radiator design becomes increasingly complex and cumbersome as the demand for power handling capability and rapid steering speed increases. Phased arrays provide an obvious solution to this problem since the power capability is limited only by the number of subradiators and the beam may be directed at the switching speeds of its controlling electronic phase shifters.

What is claimed is:

1. An iterative microwave phase shifter comprising:
   (a) a section of microwave transmission line having an electrical length of at least a plurality of quarter wavelengths at its mean frequency;
   (b) an iterative grouping of phase shifting components arranged in said section each component comprising first and second reactance means spaced substantially one quarter electrical wavelength apart at said mean frequency;
   (c) means to mount the first reactance means of each successive component in substantially the same electrical location as the second reactance means of the preceding component; and,
   (d) means to control any unbroken sequence of said components simultaneously between at least two states of reactance.

14 Claims



3,516,024 June 2, 1970

Interdigitated Strip Line Coupler

Inventor: J. Lange.
Assignee: Texas Instruments Inc.
Filed: Dec. 30, 1968.

Abstract of the Disclosure

An interdigitated coupler is fabricated from several strip lines sections with alternate sections interconnected by crossover wires. The interdigitated strip line sections are arranged such that each section is on the order of a quarter wavelength long.

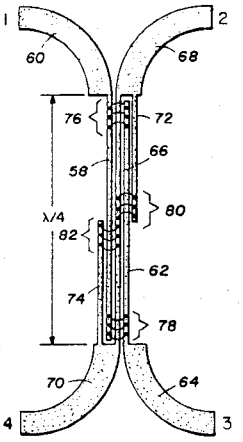
This invention relates to directional couplers and more particularly to an interdigitated quadrature strip line coupler.

A directional quadrature coupler is a four port microwave junction with properties such that a wave incident in port one couples power into ports two and three, but not into port four. Similarly, power incident in port four couples into ports two and three but not into port one. Thus, ports one and four are uncoupled. A wave incident in port two or three couples power into ports one and four only, thus ports two and three are also uncoupled. If three of the four ports are terminated in matched loads, the fourth port appears terminated in a matched load, and an incident wave in this port will be not reflected.

What is claimed is:

1. A four-port quadrature coupler comprising: a plurality of strip lines in an interdigitated pattern, each of the four ports of the coupler integral with at least one of said strip lines, and means for interconnecting alternate strip lines in the interdigitated pattern.

12 Claims



3,534,293 Oct. 13, 1970

Oscillator Circuit

Inventor: E. T. Harkless.
Assignee: Bell Telephone Laboratories, Inc.
Filed: Sept. 27, 1968.

Abstract of the Disclosure

A microwave oscillator circuit comprises a transmission line coaxial cable having a negative resistance diode mounted at one end and a dissipative impedance connected across the other end. A resonator is coupled at one end to a mid-portion of the transmission line and at the other end to a waveguide that transmits output energy to a load. The resonator is appropriately located with respect to the diode to feed back energy to the diode to maintain oscillation at the desired frequency while permitting undesired frequency components to be transmitted by the transmission line to the dissipative impedance.

Background of the Invention

This invention relates to oscillator circuits, and more particularly, to oscillator circuits using negative resistance devices.

A negative resistance oscillator basically comprises a negative resistance device connected through a resonator tuned to the desired frequency to a load

having a positive resistance "seen" by the device that is equal in magnitude to the negative resistance of the device. Typical examples of negative resistance devices used for generating microwave oscillations are the IMPATT diode, Gunn-effect diode, tunnel diode and LSA diode. With the possible exception of the Gunn-effect diode, these devices all require that energy be fed back to the diode terminals in synchronism with current through the diode to maintain continuous oscillation generation. Unfortunately, even when design precautions are taken, frequencies other than the desired frequency may be applied across the diode, causing frequency instability; that is, the appropriate conditions for oscillation may occur at frequencies radically different from the desired frequency. This susceptibility to frequency instability appears to be particularly true of IMPATT diodes, although it is also true of other negative resistance devices, and even self-contained oscillator devices such as the magnetron.

What is claimed is:

1. An oscillator circuit comprising:

a first transmission line;

means for generating oscillations at a frequency f comprising a negative resistance device mounted at one end of the first transmission line;

a matched dissipative impedance connected to the other end of the first transmission line;

a resonator having a resonant frequency f coupled to the first transmission line between the device and the dissipative impedance;

means for propagating oscillatory energy to a load comprising a second transmission line coupled to the resonator;

and means comprising the resonator for selectively channeling, from the negative resistance device to the second transmission line, oscillatory energy of frequency f while permitting energy of other frequencies to be transmitted to the dissipative impedance.

6 Claims