Oct. 28, 1952 S. ZASLAVSKY 2,615,982

DIRECTIONAL COUPLER

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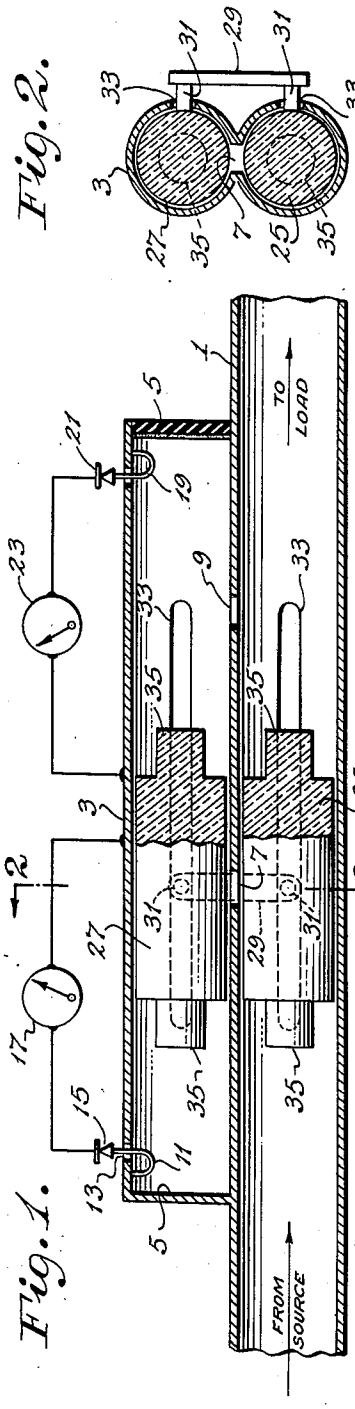


Fig. 1.

Fig. 2.

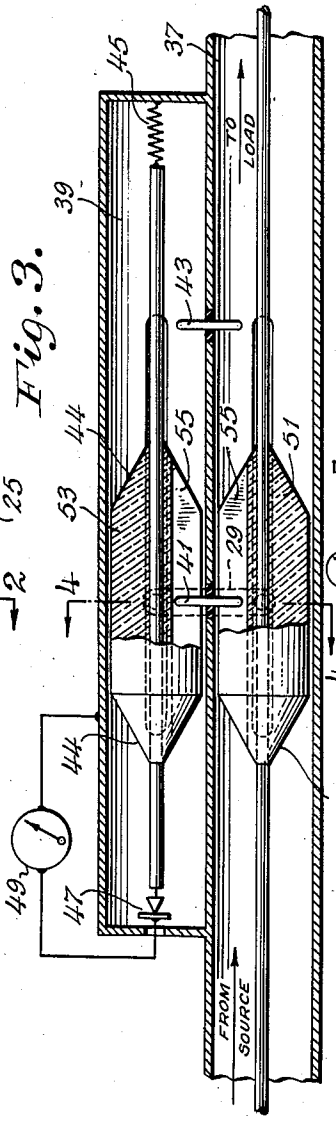


Fig. 3.

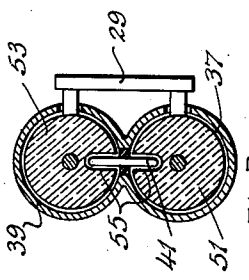


Fig. 4.

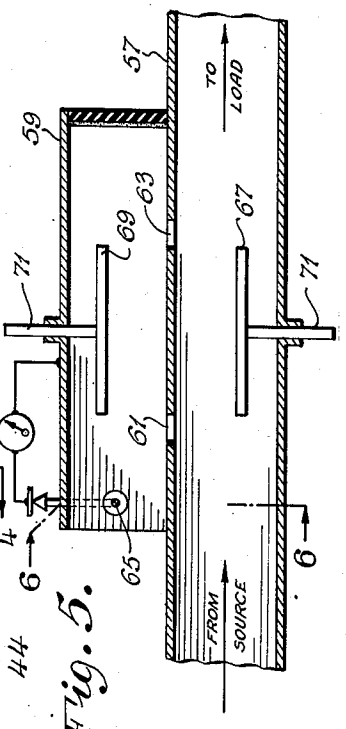


Fig. 5.

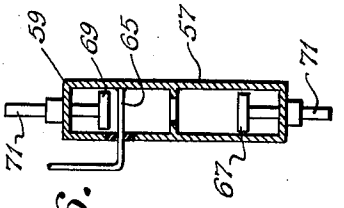


Fig. 6.

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DIRECTIONAL COUPLER

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5 Claims. (Cl. 178—44)

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This invention relates to improvements in radio frequency networks, and more particularly to so-called "directional couplers," which are devices for transferring energy flowing in one direction along one wave transmission conduit, such as a wave guide or transmission line, to a second conduit, while discriminating against such transfer of energy which flows in the other direction along the first conduit. Representative types of directional couplers are described in copending U. S. Patent applications Serial No. 499,072, filed August 18, 1943, by William W. Hansen, and Serial No. 502,734, filed September 17, 1943, by William W. Hansen and Theodore Moreno.

It is the principal object of the present invention to provide improvements in apparatus of the type described in the above-mentioned copending applications.

More specifically, it is an object of this invention to provide tunable directional couplers which may be adjusted to operate with optimum efficiency at any selected frequency within a certain band of frequencies.

Another object of the invention is to provide simple and reliable means for varying the effective lengths of certain paths through a radio frequency network, by varying the wavelength of energy in its travel over said paths.

The invention will be described with reference to the accompanying drawing, wherein:

Fig. 1 is a longitudinal section in elevation of a preferred embodiment of the invention in a measuring instrument or reflectometer;

Fig. 2 is a transverse section of the structure of Fig. 1 taken in the plane 2—2 of Fig. 1;

Fig. 3 is a longitudinal section of a modification of the device of Fig. 1;

Fig. 4 is a transverse section viewed in the plane 4—4 of Fig. 3;

Fig. 5 is a longitudinal section of a further modification of Fig. 1; and

Fig. 6 is a transverse section in the plane 6—6 of Fig. 5.

Referring to Figs. 1 and 2, a wave guide 1 in the form of a hollow tubular conductor extends from a high frequency source to a load, not shown. A second wave guide 3, similar to the guide 1, extends parallel to and adjacent the guide 1 throughout a portion of its length, as shown in Fig. 1. The wave guide 3 is terminated at one or both of its ends by absorbing means such as a disc 5 of insulating material coated with graphite or other resistive substance of such thickness as to match the impedance of the guide and thereby prevent reflection of energy incident on the end of the wave guide.

An aperture 7 is provided in the walls of the guides 1 and 3, opening between the interiors of the two guides. A second similar aperture 9 is

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provided at a point longitudinally separated from the aperture 7 by one quarter wavelength, or an odd integral number of quarter wavelengths, at substantially the highest frequency at which the system is to operate. A small coupling loop 11 near one end of the guide 3 is connected through an aperture 13 to a detector such as a crystal 15. A current meter 17 is connected in series with the detector 15, the return connection being made through the grounded wall of the guide 3. A second loop 19 may be provided near the other end of the guide 3, and connected to a detector 21 and a meter 23.

The structure thus described is similar, though not exactly identical to, that shown in the aforementioned copending application Serial No. 502,734. In the operation of the device some of the energy travelling left to right in the guide 1, i. e., from the source to the load, escapes through the apertures 7 and 9 into the guide 3. Each aperture acts as a radiator, emitting energy which divides into two components, one travelling leftward in the guide 3 and the other travelling rightward.

Since the excitation of the aperture 9 is delayed one-quarter wavelength or 90 degrees with respect to that of the aperture 7, and the leftward component from the aperture 9 is further delayed another 90 degrees in travelling along the guide 3 to the aperture 7, the two leftward components are 180 degrees out of phase at the aperture 7 and thus cancel each other. Consequently no energy travels leftward in the guide 3 as a result of energy travelling rightward in the guide 1. The rightward components radiated into the guide 3 by the apertures 7 and 9 are in phase at the aperture 9, and energy does travel rightward in the guide 3. This energy may be picked up by the loop 19, rectified by the detector 21, and indicated by the meter 23.

As long as the load end of the guide 1 is matched, no energy flows from right to left therein and none is picked up by the loop 11. However, any mismatch will cause reflection, producing a flow of energy from right to left in the guide 1. This induces a flow from right to left in the guide 3, energizing the loop 11. The energy picked up by the loop 11 is rectified by the detector 15 and indicated by the meter 17.

From the foregoing it will be apparent that the meter 23 indicates the amplitude of the direct wave; the meter 17 indicates the amplitude of the reflected wave, and the standing wave ratio may be computed as the quotient of the two readings. This is based on the assumption that the spacing between the apertures 7 and 9 is substantially exactly one-quarter wavelength, or an integral odd number of quarter wavelengths.

At frequencies where the distance between the apertures 7 and 9 is not a quarter wavelength,

the leftward components of the radiation from the apertures into the guide 3 will not be in phase opposition, and a resultant energy flow to the left will be produced by waves moving to the right in the guide 1. Similarly, reflected waves moving to the left in the guide 1 will induce waves flowing to the right in the guide 3, and the device will fail to operate as a directional coupler, since it can no longer distinguish between rightward and leftward flow in the guide 1.

In accordance with the instant invention, means are provided for tuning or adjusting the coupler to operate properly at any one selected frequency, by changing the effective spacing between the apertures 7 and 9. This is effected by altering the wavelength in the guides of energy travelling between the two coupling points. In the example of Fig. 1, cylindrical bodies or slugs 25 and 27 of dielectric material are provided in the guides 1 and 3 respectively. The slugs 25 and 27 are composed of polystyrene or other low-loss material, and preferably are of lengths approximately equal to the spacing between the apertures 7 and 9.

The slugs 25 and 27 are movable longitudinally within the respective wave guides. As shown in Fig. 2, they are gauged or mechanically coupled together by a bar 29 secured to the slugs by short rods 31 extending through longitudinal slots 33 in the walls of the guides. The ends of the slugs may be formed, as with portions 35 of reduced cross section (see Fig. 1), to provide impedance matching to the air-filled guide.

The effect of a body of dielectric material in a wave guide otherwise filled with a lower dielectric material, such as air, is to reduce the wavelength of energy travelling in the guide in the part which is filled with the higher dielectric material. In other words, the part filled with higher dielectric material has a greater effective length, measured in wavelengths, than a part of equal physical lengths which is not so filled.

As mentioned above, the distance between the apertures 7 and 9 may be one-quarter wavelength at the highest frequency at which the system is to operate. At this frequency, the slugs 25 and 27 may be omitted, or may be moved either to the left or to the right to a position such that none of the dielectric material is in the space between the two apertures.

Now suppose it is desired to operate with energy of a lower frequency. The two slugs 25 and 27 are then moved together, by means of the bar 29, to a position like that shown in Fig. 1 with part of the dielectric material lying between the apertures. Since the wavelength in the slugs is shorter than in the air-filled guide, a position can be found where the effective electrical distance between the apertures is exactly one-quarter wavelength, providing the frequency is not too greatly different from the maximum frequency of operation. The device then operates substantially as described above, with the unimportant exceptions that a certain fixed phase shift is introduced between the source and the load by the slug 25, and the leftward going and rightward going waves in the guide 3 are shifted with respect to each other.

Although the nominal distance between the apertures 7 and 9 may be made one-quarter wavelength, it may be preferable to use a greater spacing, for example, nine quarter wavelengths. This has two advantages; first, that the matching sections 35 may be long enough to be reasonably effective, and second, that the range of adjustability of the device as to frequency may be extended greatly. The latter point may be made clear by considering the fact that the longer the slugs are, the more total change in phase they will produce. If they are made only long enough to provide a total phase change of substantially 180 degrees, they will be sufficient to cover a wide frequency band because, as the frequency is lowered, the original nine quarter wavelength spacing may be used as seven quarters, five quarters, and so on. It is probable that by this method, the range of adjustability may be made great enough to cover the entire band over which the waves guide themselves will operate effectively.

While only two coupling elements or apertures are shown in Fig. 1, it will be understood that the present invention is similarly applicable to other known types of directional couplers using three or more spaced coupling elements, or a single distributed element such as a relatively long slot.

Although the invention has been described as embodied in a wave guide arrangement, it may be applied also to an analogous system using transmission lines. Referring to Figs. 3 and 4, a coaxial line 37 extends from a source to a load, not shown, and a second line 39 lies parallel and adjacent to the line 37, being coupled thereto by probes 41 and 43 which extend through the sheathes of the two lines to points near the inner conductors. The line 39 may be terminated by a resistor 45, of a value equal to the characteristic impedance of the line. One end of the line 39 is coupled for example by direct connection from the inner conductor to a detector 47 and a direct current meter 49. Substantially cylindrical slugs 51 and 53 of polystyrene or similar material are provided in the lines 37 and 39 respectively, preferably substantially filling the radial space between the inner and outer conductors throughout a longitudinal distance of the same order as the distance between the probes 41 and 43. The slugs may be tapered as at 44 for impedance matching. The dielectric slugs are provided with longitudinal slots 55 (Fig. 4) to accommodate the probes and allow the slugs to be moved. A bar 29 couples the two slugs together, as in the system of Fig. 1.

The operation of the device of Fig. 3 is similar to that of Fig. 1, in the production of leftward and rightward components in the line 39 in response to direct and reflected waves in the line 37. Also as in the system of Fig. 1, the dielectric slugs effectively lengthen the part of the line in which they lie, and they may be moved between the coupling points to the extent required to make the electrical spacing one-quarter wavelength.

As mentioned above in connection with Fig. 1, the number of coupling elements is not necessarily two. It should also be noted that the degree of coupling provided by either a probe or an aperture, or any other known type of coupling element which might be used, such as a loop, will depend upon the dielectric constant of the material in its vicinity, as well as upon the size and shape of the coupling element. Thus, in designing any coupling element to provide a certain amount of coupling, consideration must be given as to whether or not the element is to operate near or within one of the dielectric slugs.

It will be apparent without further explanation that the present invention is not limited to directional couplers wherein the primary and secondary conduits are of the same type. For ex-

ample, the primary or main line may be a hollow wave guide and the secondary may be a coaxial line section, or vice versa. Furthermore, the primary and secondary guides need not be substantially parallel, but may be crossed or skewed with respect to each other, as in certain known types of prior art directional couplers.

Variation of the wavelength in a guide, and hence of the electrical length of a certain section of a wave guide, may be achieved by changing the position of a sheet or block of dielectric transversely of the guides.

Referring to Figs. 5 and 6, a rectangular wave guide 57 carries energy from a source to a load, and a second similar guide 57 is coupled thereto by apertures 61 and 63. A probe 65 extends parallel to the electric vector in the guide 59 near one end thereof, and is connected through a detector 15 to a meter 17. The structure is similar to that of Fig. 1, and operates as a directional coupler in substantially the same way. In order to provide the required phase shift at different frequencies relatively thin blades or sheets 67 and 69 are supported on rods 71 for motion transversely within the guides 57 and 59 respectively.

When the members 67 and 69 are positioned near the walls of their respective guides where the electric fields are relatively weak, their effect is at a minimum. To increase the phase shift, i. e., the effective distance between the coupling apertures, the bodies 69 and 67 are moved toward the centers of the guides, where the field intensity is greatest.

The invention has been described as an improvement in directional couplers which may be adjusted or tuned for best operation with energy of any selected frequency. This is accomplished by varying the effective lengths of the paths between coupling elements, by means of bodies of dielectric material wherein the wavelength of the energy is less than in air. The slugs are movable to include more or less dielectric material in the paths whose electrical lengths are to be altered, or to lie in regions of greater or less field intensity and thereby vary the effective path lengths.

Although it is generally preferable at present to vary the effective path lengths between the coupling elements in both conduits together, as described above, it is practicable to vary the path length in only one conduit, adjusting for minimum transmission in one direction. Transmission in the other direction will also be reduced somewhat, but not seriously except at frequencies very far from the center or design frequency of the apparatus. The dielectric body may be omitted from the conduit in which the path length is not adjusted, or may be fixed in position therein.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In a network for high frequency radio energy, a wave transmission conduit adapted to be connected between a source and a load, a second wave transmission conduit substantially parallel to and adjacent said first conduit, means

coupling a point on said first conduit to a proximate point on said second conduit, further means coupling a second point on said first conduit to a respective proximate point on said second conduit, a body of dielectric material within said first conduit and movable therein for altering the wavelength between said first and second points in said first conduit of energy flowing therein with respect to the wavelength of said energy in the remainder of said conduit, and a second body of dielectric material movable within said second conduit for similarly altering the wavelength between said corresponding points in said second conduit of energy flowing in said second conduit, whereby the effective electrical spacing between said first and second points longitudinally of said conduits may be made substantially a predetermined odd number of quarter wavelengths at any particular frequency within a band of frequencies.

2. The invention as set forth in claim 1, wherein said dielectric bodies are movable transversely within the respective conduits to vary the electric field distribution therein, at least a portion of each of said elements being disposed between said first and second coupling means.

3. The invention as set forth in claim 1, wherein each of said dielectric bodies is approximately as long as the spacing between said coupling means, and is movable longitudinally from a position filling the interior of the respective conduit between said coupling means to a position substantially external to the space between said coupling means.

4. The invention as set forth in claim 1, wherein said first and second points in each said conduit are spaced apart longitudinally of said conduit by at least one and one-quarter wavelengths at the mean frequency at which the system is to operate, and said dielectric bodies each have a longitudinal extent greater than one quarter wavelength and are provided with low-reflection sections at their ends.

5. In a network for high frequency radio energy, a wave transmission conduit adapted to be connected between a source and a load, a second wave transmission conduit, means coupling a plurality of spaced points on said first conduit respectively to a plurality of corresponding spaced points on said second conduit, and a body of dielectric material within one of said conduits and movable therein for altering the wavelength between said points in said conduit of energy flowing therein with respect to the wavelength of said energy in the remainder of said conduit.

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