

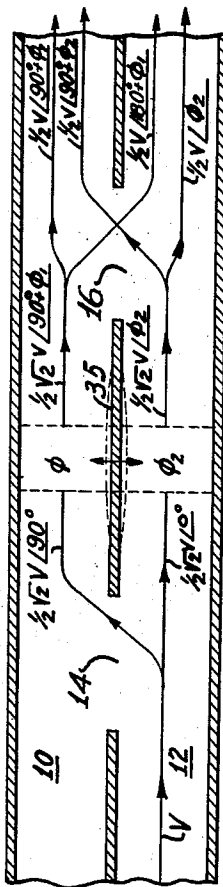
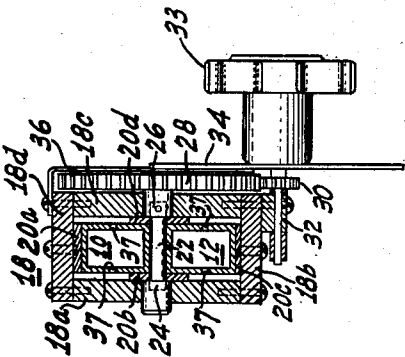
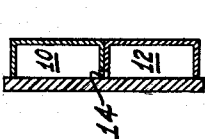
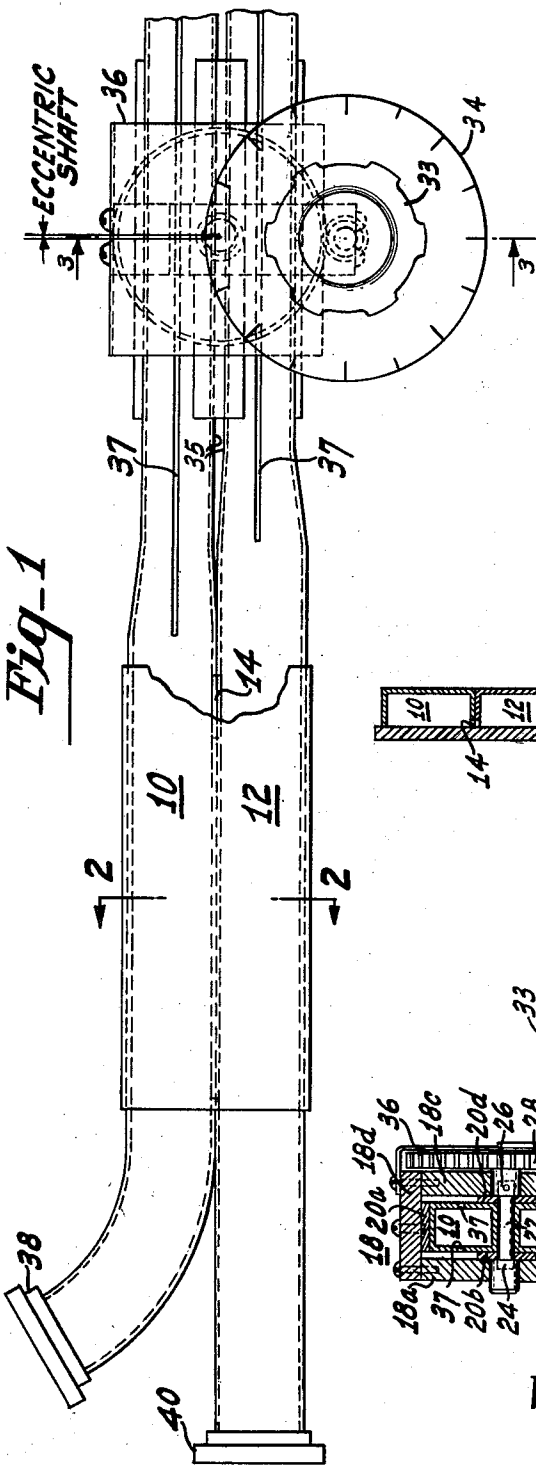
May 25, 1954

N. I. KORMAN ET AL
POWER DIVIDER

2,679,631

Filed Oct. 2, 1950

2 Sheets-Sheet 1



INVENTORS
**Nathaniel I. Korman &
Waldon Pearson Bollinger**
BY *J. L. White*
ATTORNEY

May 25, 1954

N. I. KORMAN ET AL

2,679,631

POWER DIVIDER

Filed Oct. 2, 1950

2 Sheets-Sheet 2

Fig-6

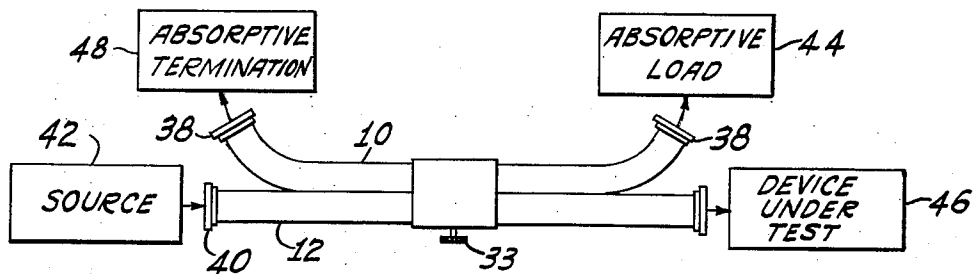
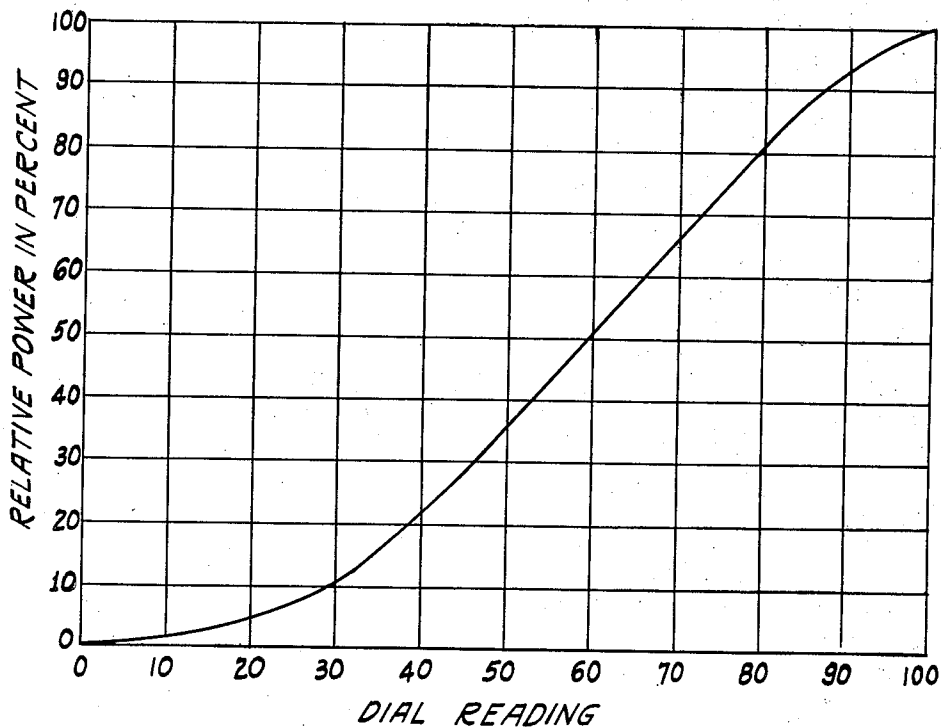


Fig-5

INVENTORS
*Nathaniel I. Korman &
Waldon Pearson Bollinger*
BY *J. L. Whitaker*
ATTORNEY

UNITED STATES PATENT OFFICE

2,679,631

POWER DIVIDER

Nathaniel I. Korman, Merchantville, and Waldon P. Bollinger, Haddonfield, N. J., assignors to Radio Corporation of America, a corporation of Delaware

Application October 2, 1950, Serial No. 188,032

13 Claims. (Cl. 333-7)

1

This invention relates to power dividers for high frequency systems.

In the testing of components, it is often desirable to have available a means of varying the power from a source over wide limits. For example, in the testing of waveguide components for high power carrying capacity, a variable power source is desirable. Heretofore, attenuators have been commonly used to provide the desired power variation. The usual methods, however, are either subject to low power handling capacity or are bulky and awkward.

It is an object of the present invention to provide an improved means of varying the power output along a transmission line.

Another object of the invention is to vary continuously the power output to a transmission line.

Still another object of the invention is to provide a variable power divider network of high power handling capacity.

Further objects of the invention are to provide a power divider which is compact, the power division of which is readily and easily controlled, and which is reliable in operation. Also a further object of the invention is to provide a phase shifter which shifts phase simultaneously in two waveguides.

In general, it is found preferable to use the principles of power division between two transmission lines rather than attenuation by variable absorption in the conventional manner. The unwanted power is diverted into a preferably fixed load, which may readily absorb high power, and the remaining undiverted power is passed on to the device under test (or vice versa, of course).

In accordance with the invention, a pair of transmission lines have between them a pair of spaced apart directional couplers each characterized by a phase change of substantially 90 degrees in incident energy transferred through the coupler from one line to the other, and means are provided to shift the phase or to vary the effective line length of at least one of the transmission lines between the effective points of coupling. With this variation, the energy division between the two waveguides is varied. If the energy in one line is thus increased, that in the other is decreased, and vice versa. Preferably, the effective line length between the couplers in one line is increased and that in the other decreased simultaneously, and a novel waveguide phase shifting arrangement is employed for the purpose.

The foregoing and other objects, advantages,

2

and novel features of the invention will be explained more fully in connection with the accompanying drawing in which like reference numerals refer to like parts and in which:

Fig. 1 is a front elevational view of a preferred embodiment of the invention except that a portion symmetrical with that shown is omitted;

Fig. 2 is a sectional view along the lines 2-2 of Fig. 1, showing a directional coupling between two waveguides;

Fig. 3 is a sectional view along the lines 3-3 of Fig. 1 showing a phase shifting means;

Fig. 4 is a simplified schematic longitudinal sectional view parallel to the plan view of Fig. 1, especially useful in explaining the operation of the embodiment of Fig. 1;

Fig. 5 is a circuit diagram schematically illustrating employment of the device of Figs. 1 to 4; and

Fig. 6 is a calibration curve for a specific device such as that illustrated in Fig. 1.

The directional couplers mentioned above are exemplified in the illustrated preferred embodiment by directional slot couplers between a pair of waveguides, which exemplify the transmission lines, and the variation in effective line length is preferably accomplished by a simple, well-known line-stretcher or phase shifter arrangement. The line length variation of the present arrangement in which the variations are reciprocal and complementary is preferred because of the superior performance of this arrangement.

Referring now more particularly to Figs. 1 to 4, a pair of rectangular waveguides 10 and 12 are coupled by a pair of spaced slots 14 and 16 which are directional slot couplers. Each slot is placed at one edge boundary of a common wall portion in the narrow walls of the rectangular waveguides. The slot couplers 10, 12 each transfer half the energy incident from one waveguide 10, 12 to the other with a 90 degree phase shift. The properties of such couplers are known and described, for example, in the copending application of Waldon P. Bollinger, Serial No. 73,838, filed January 31, 1949, and entitled "Transmit-Receive Arrangement" and also described in the publications cited in the said application.

Various types of linear passive directional couplers between transmission lines are known in which the energy incident in one direction along one transmission line is coupled directionally one-half to another transmission line, half the incident energy continuing along the first line in its initial direction and the other half traveling in one direction along the coupled line and

in which the energy in the coupled line is phased 90 degrees with the energy in the first line. See, for example, the article by Henry J. Riblet entitled "Mathematical theory of directional couplers," Proceedings of the I. R. E., November 1947, page 1307 and also "Technique of Microwave Measurements" by Montgomery et al., Radiation Laboratories Series, volume 11, section 14.8 starting at page 885. The directional coupler selected as a suitable example in the arrangement disclosed herein is a long-slot coupler between hollow pipe waveguides. However, it will be apparent that other types of directional couplers may be employed wherever suitable for the transmission lines used.

Between the slots 14, 16, there is provided a frame 18 which includes frame members 18a, 18b, 18c, and 18d, which grasp between them a portion of the waveguides 10, 12 through the intermediary of plates 20a, 20b, 20c, and 20d. The frame 18 and the plates are held together rigidly with suitable bolts as shown. Between the waveguides 10, 12 and in the frame is journaled a shaft 22 which is eccentric with respect to its bearings 24, 26 in the frame 18. The shaft 22 is attached to a gear 28 centered on the bearing 26. The gear 28 is driven by a second gear 30 meshing therewith and held in a bearing 32 attached to the frame 18. A knob 33 is also attached to the gear 30 and a dial 34 is engaged with the knob. The dial 34 is read against a dial plate 36 attached to the frame 18. The broad waveguide walls are arranged transverse to the eccentric motion of the eccentric shaft 22 and are slotted with longitudinal slots 37 near the wall portion movable by the eccentric shaft 22. The slots afford elasticity permitting the expansion or compression of the broad dimension of waveguides 10 or 12. Of course, slots 37 are preferably made narrow to inhibit the escape of any except a negligible amount of energy. The eccentric shaft portion 22 extends between the narrow waveguide walls and affords a reciprocal and complementary motion of the narrow wall portions between slot couplers in the waveguides 10, 12. Those skilled in the art will understand that the adjacent narrow walls of waveguides 10, 12 at the place where the eccentric bears against them may be considered as a common wall portion illustrated in the simplified schematic of Fig. 4 as a wall 35, the transverse motion of which is indicated in Fig. 4 by the arrows. At its ends the waveguide 10 has couplers 38 (only one of which is shown in Fig. 1) and waveguide 12 has couplers 40 which may be of the standard type of choke joint coupling. These afford means for coupling to other circuit elements. In Fig. 1, the remainder of the structure to the right of the dialed portion may be considered symmetrical with the portion shown to the left of the dialed portion. This right end portion has been omitted in Fig. 1 because it would be difficult to suitably proportion the figure and show all of the details necessary.

In operation (refer also to the much simplified circuit diagram of Fig. 5 for a typical circuit application), assume that energy enters from the left into one of the waveguides, say 12 from a source 42. The energy is incident in direction toward the right as viewed in Fig. 1 or 4 or 5. When the energy arrives at the directional coupler 14, it begins to be transferred into waveguide 10. In accordance with the theory in the publications to which reference has heretofore been made, and as also explained in the said co-

pending application, the slot 14 has a sufficient length to couple half the energy into waveguide 10. Thus let the total energy have a voltage maximum designated by V. The transferred energy is then

$$\frac{1}{2}\sqrt{2V} |90^\circ$$

The energy remaining in waveguide 12 to the right of the coupling slot 14 is

$$\frac{1}{2}\sqrt{2V} |0^\circ$$

In the portion between slot 14 and slot 16, the energy in waveguide 10 is shifted by an angle $90^\circ + \phi_1$ and that at waveguide 12 by an angle ϕ_2 . The resultant energy values, relatively considered, still travelling to the right as viewed in Fig. 1 or 4, are

$$\frac{1}{2}\sqrt{2V} |90^\circ + \phi_1$$

and

$$\frac{1}{2}\sqrt{2V} |\phi_2$$

At the slot 16 each of the energy incident from the left in waveguide 10 and in waveguide 12 splits again. The energy from waveguide 10 divides with an amount

$$\frac{1}{2}V |90^\circ + \phi_1$$

continuing in waveguide 10 and

$$\frac{1}{2}V |180^\circ + \phi_1$$

transferred to waveguide 12. The energy incident toward the right from waveguide 12 divides with

$$\frac{1}{2}V |90^\circ + \phi_2$$

transferred to waveguide 10 and

$$\frac{1}{2}V |\phi_2$$

continuing in waveguide 12. Accordingly, the components in waveguide 10 can be combined and result in a wave of voltage amplitude

$$V \sqrt{\frac{1 + \cos(\phi_1 - \phi_2)}{2}} \quad (1)$$

For waveguide 12 the voltage amplitude is

$$V \sqrt{\frac{1 - \cos(\phi_1 - \phi_2)}{2}} \quad (2)$$

It is apparent that the power division between waveguides 10 and 12 can be controlled by control of the phase shifts ϕ_1 and ϕ_2 . The phase shifts can be controlled singly, that is, ϕ_1 can be controlled or varied without variation of ϕ_2 and vice versa if desired. Preferably, however, in order to provide a more linear calibration curve and in order to make the phase shifting apparatus as symmetrical as possible with respect to the motion thereby tending to compensate for opposite errors and toward linearity of calibration, it is preferred to shift phases in opposite directions from a calibration point in which they differ by 90° . This is readily accomplished by the structure shown in greater detail in Figs. 1 to 3. It will be observed that between the couplers 14, 16, both waveguides 10 and 12 have their broad dimension or width narrowed generally in the vicinity of the slots 37. The narrowed or necked down portions are for the purpose of increasing the variation in phase shift with motion of the narrow effectively common wall. However, it will be observed that the narrowed portion of waveguide 10, is somewhat longer than the narrowed or necked down por-

tion of waveguide 12. This means that effective length of waveguides 10 and 12 between the effective points of coupling of the couplers are different. This effective difference in length is made 90° so that the common wall portion 35 when at the neutral point of the eccentric shaft 22 is substantially straight and undeformed. This is equivalent to choosing ϕ_1 to exceed ϕ_2 by 90° at the neutral position. As the eccentric is rotated from this neutral position in one direction, one of the waveguides 10 is squeezed in the necked down portion to have its width further reduced while the other waveguide has its width expanded or increased simultaneously and vice versa. Thus the difference in line lengths is varied. Preferably, the eccentric is arranged so that the difference in the extreme shifts is just 45° and in opposite directions. Accordingly, the power transfer may extend all the way from zero reaching absorptive load 44 connected to waveguide 10, to 100%, and similarly from a 100% reaching the device under test 46 through waveguide 12 to zero. The connections of load 44 and the device under test 46 may be interchanged if desired. The termination 48 may be simply a low power termination and absorbs any power reflected toward it resulting from imperfections in the directional couplers. Ideally, this reflected power is zero. In practice, it is usually very small, of the order of 1% of the total power handled. The connections of terminations 48 and source 42 may also be interchanged if desired.

A typical calibration curve is illustrated in Fig. 7 of the drawings. It will be understood that the construction is preferably such that a substantially half dial turn is required to obtain a turn of the eccentric in one direction resulting in a 90° phase shift in one direction in each of waveguides 10, 12, and a half dial turn in the other direction is required to obtain a turn of the eccentric in the other direction with an opposite resulting phase shift. Thus the dial reading 50 in Fig. 5 would correspond substantially to a neutral position of the eccentric and the relative power in percent is that transferred to the waveguide corresponding to waveguide 10 as illustrated in the drawings. The curve is in fact asymmetrical probably due to the difference in the necked down waveguide portions.

It will be understood that it is not necessary that a directional slot coupler between the two waveguides be used since there are other arrangements which electrically are equivalent to that shown. The arrangement illustrated is preferred, however, because it is particularly compact, neat, and considering the frequencies and the power involved (frequencies of the order of 3 centimeters and amplitudes involving 1,000 kilowatts), is fairly simple to construct.

It is apparent that there is disclosed a highly desirable, readily constructed variable power divider. The energy travelling through one of the waveguides 10, 12 may be directed to and dissipated in a dummy absorptive load or the like, in desired proportion whereas the energy travelling in the other branch may go to a device under test. Large amounts of microwave power may thus be readily divided as desired by the device of the invention. There is also disclosed a novel phase shifter of convenient and economical construction for use with two waveguides. It may be noted that the positions of the source 42 may be at either connection on one side and that of the device under test at either connec-

tion on the opposite side of the divider toward which the energy is directed.

What we claim as our invention is:

1. A power divider comprising a pair of transmission lines, a pair of spaced linear passive directional couplers between said lines each characterized by a phase change of substantially 90 degrees in energy transferred through the coupler from one line to the other, and each characterized by a transfer of one half the energy incident at the coupler from one line directionally into the other, and means to adjust the effective relative lengths of said lines between the effective points of coupling of said couplers.

2. A power divider comprising a pair of transmission lines, a pair of spaced linear passive directional couplers between said lines each characterized by a phase change of substantially 90 degrees in energy transferred through the coupler from one line to the other, each said line between said couplers being effective to transfer energy from one effective coupling point of said couplers to the other substantially without change in amplitude, and means to adjust the effective relative lengths of said lines between the effective points of coupling of said couplers.

3. A power divider comprising a pair of transmission lines, a pair of spaced linear passive directional couplers between said lines each characterized by a phase change of substantially 90 degrees in energy transferred through the coupler from one line to the other, and means to vary the effective line lengths between the effective points of coupling of said couplers with one of said lengths increasing while the other decreases and vice versa.

4. The divider claimed in claim 1, said transmission lines being hollow pipe waveguides.

5. The divider claimed in claim 1, said transmission lines being hollow pipe waveguides, said couplers each being a long slot coupler in a common waveguide wall portion.

6. The divider claimed in claim 1, said transmission lines being hollow pipe waveguides, said effective line lengths being varied by variation of a waveguide width.

7. The divider claimed in claim 1, said transmission lines being hollow pipe waveguides, said waveguides having a common wall portion between said couplers, the effective line lengths of both said lines being varied reciprocally and simultaneously by transverse motion of said wall portion.

8. A power divider comprising a pair of rectangular hollow pipe waveguides having broad and narrow walls and having between the narrow walls thereof a pair of spaced apart directional slot couplers, and a common wall portion between said couplers, each coupler being characterized by a phase change of substantially 90 degrees in incident energy transferred through the coupler from one guide to the other, and means to move transversely said common narrow wall portion, thereby simultaneously increasing the width of one waveguide and decreasing the width of the other at said common wall portion.

9. The divider claimed in claim 8, said broad walls of said waveguides being longitudinally slotted near said common movable wall portion.

10. The divider claimed in claim 8, further comprising a frame around said waveguides between said slot couplers, a shaft journaled in said frame and having an eccentric portion transversely between said narrow walls whereby rotation of the shaft moves an effectively common

wall portion between said couplers simultaneously to increase one waveguide width and decrease that of the other.

11. The divider claimed in claim 10, further comprising a manually adjustable dial geared to said shaft. 5

12. A power divider comprising a pair of transmission lines, a pair of spaced linear passive directional couplers between said lines characterized by a phase change of substantially 90 degrees in energy transferred through the coupler from one line to the other, and each characterized by a transfer of one half the energy incident at each coupler from one line directionally into the other, each said line between said couplers being effective to transfer 15 energy from one effective coupling point of said couplers to the other substantially without change in amplitude, and means to adjust the effective relative lengths of said lines between 20 the effective points of coupling.

13. A power divider comprising a pair of transmission lines, a pair of spaced linear passive directional couplers between said lines characterized by a phase change of substantially 90 degrees in energy transferred through the coupler from one line to the other, the transmission paths from one said coupler to the other consisting solely of said lines, and means to adjust the effective relative lengths of said lines between the effective points of coupling of said couplers.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,423,526	Sontheimer et al. ---	July 8, 1947
2,543,425	Strandberg -----	Feb. 27, 1951
2,560,806	Lewis -----	July 17, 1951
2,586,993	Riblet -----	Feb. 26, 1952
2,593,120	Dicke -----	Apr. 15, 1952