

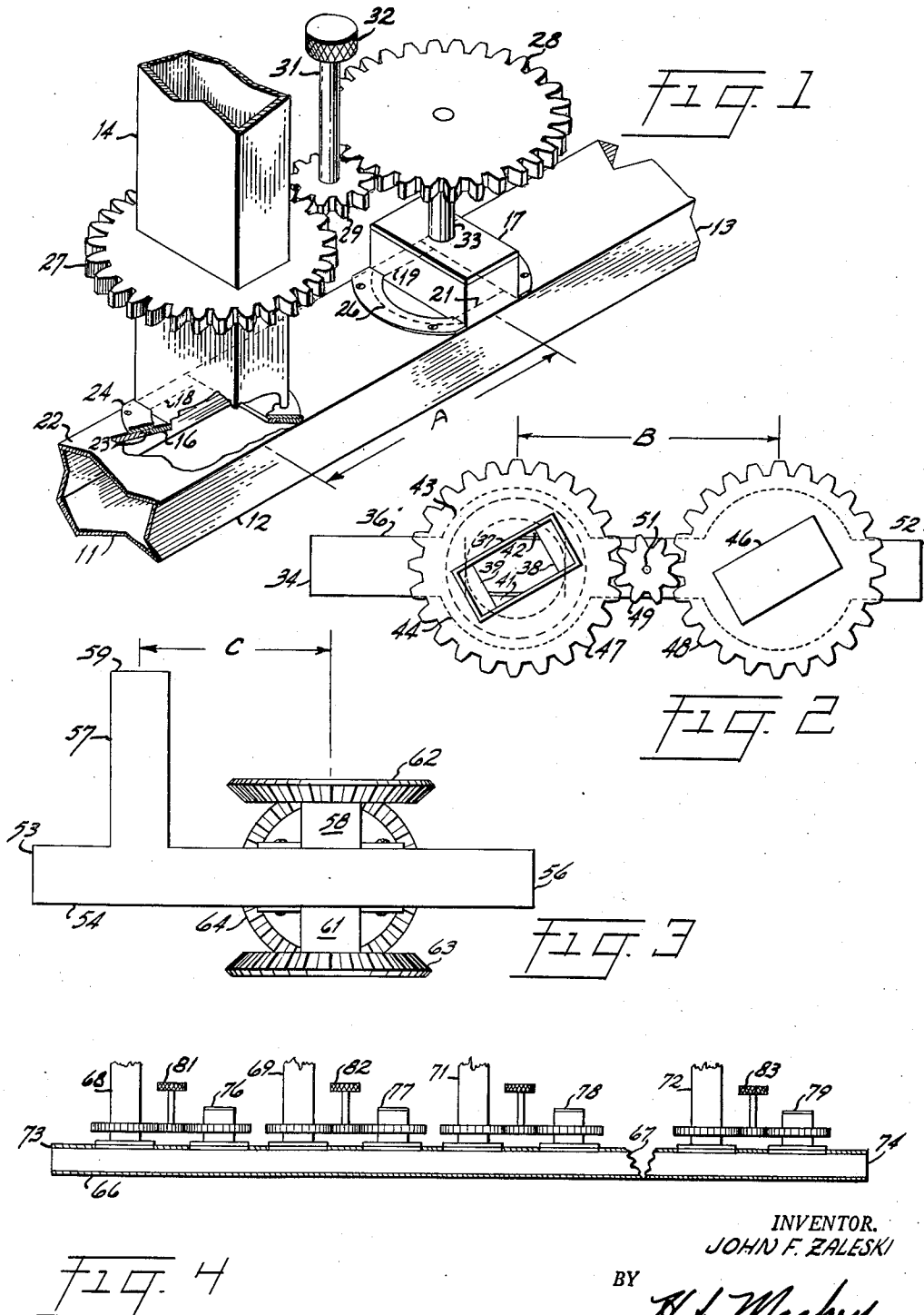
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MICROWAVE POWER DIVIDER

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MICROWAVE POWER DIVIDER

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This invention pertains to an adjustable microwave energy controlling device and more particularly to a device capable of apportioning microwave energy between a plurality of output branches while presenting substantially constant impedance to the microwave generator or other input circuit.

In controlling large amounts of microwave energy the need arises for the efficient division of the energy between a plurality of output terminals in the desired ratio, varying from full energy at one outlet to full energy at the other, while maintaining a constant impedance load on the generator or other input circuit for supplying microwave energy to the power divider. Devices now employed for low-power control are not applicable to outputs greater than about 10 watts of average power.

The instant invention provides an improved device for controlling microwave energy over a wide range and is easily and continuously adjustable. The device causes substantially no reflection, so that with it voltage standing wave ratios of less than 1.05 are obtainable.

For purposes of simplicity and clarity, since a wave guide or a coupling iris through which microwave energy is transferred from one guide to another corresponds to the two conductors of circuits for currents having frequencies below the microwave range, such irises or wave guides will be referred to herein as "terminals."

The device consists essentially of a section of hollow rectangular wave guide employing one end as a fixed microwave input terminal and the other end as a fixed microwave output terminal. The rectangular guide section has at least one rectangular side outlet arm and at least one associated guide stub for matching purposes. By rotation of these side arms and stubs, or of the stubs alone, the input microwave power is switched or divided between or among several output terminals. Any termination desired can of course, be employed at each output terminal, each termination being a useful load such as an antenna or a dummy load such as a power-dissipating attenuator, but in any case there should not be such impedance mismatch between the guide and the load as to cause reflections, in accordance with the usual practice. With the proper matching, the device of the present invention is capable of handling large amounts of microwave energy with substantially no change of its input impedance over its entire range of adjustment. Because there is no substantial reflection of energy back into the generator or energizing circuit, the breakdown voltage of the power divider is not

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substantially less than that of the microwave guide composing it.

One purpose therefore, of this power divider is adjustably to apportion microwave energy between a plurality of output terminals without any substantial change in the input impedance.

A better understanding of this invention can be had from the detailed description and the reference drawings, in which:

Figure 1 illustrates a microwave power controlling device having a rotatable series arm and quarter-wave stub.

Figure 2 illustrates a microwave power controlling device having a rotating shunt arm and quarter-wave stub.

Figure 3 illustrates a microwave power controlling device having a stationary side arm and two rotating quarter-wave stubs.

Figure 4 illustrates schematically a microwave power controlling device having a larger number of output terminals.

Referring now to Fig. 1, microwave energy of any preselected wavelength is applied to the open end 11 of a length of hollow rectangular wave guide 12 having appropriate dimensions to transmit the dominant mode, TE_{10} , of microwave energy of a specific wavelength therein. The microwave energy may be secured from any source and be applied to the open end 11 by any known technique, as through a welded, butt or lapped flange joint. The other end 13 of the wave guide 12 is open for connection as an output terminal to any desired useful or dummy load, which should of course, have an input impedance matched to the characteristic impedance of the guide 12. A rectangular guide series type side arm 14 is connected to the guide 12 at any convenient point by means of a turntable 15, so that the arm 14 can be rotated about its longitudinal axis. When the arm 14 is in the position shown it intercepts microwave energy passing through the guide 12, but when the arm 14 is rotated 90° from the depicted position so that its transverse axis is in line with the longitudinal axis of the guide 12 no energy is intercepted by the arm 14. At intermediate angles of rotation of the arm 14 on its turntable 15, a proportionate amount of energy will be intercepted by the arm 14 and the remainder will pass on to the guide output terminal 13.

In order to divert the microwave energy into the arm 14 when in its series or crosswise position, and to restrict the flow out of the terminal end 13, it is necessary to provide a quarter-wave short-circuited stub arm 17. This quarter-wave stub 17 is positioned a distance A from the arm

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14 on the side away from the input terminal end 11, the distance A being

$$\frac{M\lambda_g}{4}$$

where λ_g is the wavelength in guide and M is any odd integer. The stub 17 is rotatable in concert with the arm 14.

The amount of energy extracted by the arm 14 is then given by the equation

$$E=P \cos^2 \alpha$$

in which E is the energy extracted, P is the energy applied to the input terminal 11 and α is the angle through which the arm 14 and stub 17 are turned from their positions shown in Fig. 1.

In order to match the side arm 14 and the stub 17 to prevent discontinuity and reflection at their junctions with the guide 12, any conventional means may be employed such as the insertion of a coupling iris at each junction. Symmetrical inductive irises are used in the example, somewhat restricting the larger cross sectional dimensions, several of the vanes thereof being shown dotted at 18, 19 and 21 in Fig. 1.

The turntable 16, upon which the arm 14 is mounted so that it can be rotated about its axis, is keyed into one of the broad faces 22 of the rectangular guide 12 by means of a stepped joint 23, and a retaining annulus 24 is positioned so as to hold the turntable 16 in place while permitting its rotation. The quarter-wave stub 17 is mounted upon a similar turntable 26.

It is necessary, when rotating the arm 14 in changing the ratio of division of power, to rotate the quarter-wave stub 17 simultaneously therewith and by the same angular amount. Such rotation keeps each point of the quarter-wave stub 17 at the prescribed distance from its analogous point in the output side arm 14. The phase of the energy reflected back by the quarter-wave stub 17 will therefore during rotation be correct at each point of the junction of the arm 14 with the guide 12 to reinforce the energy from input end 11 without the appearance of a discontinuity at the junction.

The simultaneous rotation of the side arm 14 and the quarter-wave stub 17 is effected by means of two identical gears 27 and 28; gear 27 being fixed to the arm 14 and the gear 28 being attached to the stub 17, and a driving pinion 29 being positioned to mesh with both of them. In order to make the drawing clearer the two gears 27 and 28 and the pinion 29 are shown in somewhat exploded view relation, and the shaft 33 is intended to indicate attachment of the gear 28 to the quarter-wave stub 17. The driving pinion 29 is fixed to a shaft 31 having a knob 32 for manual operation, but, of course, the rotation may as well be effected by remote control, or automatic means.

In Fig. 2 a similar arrangement employing the shunt type rectangular guide side arm and a shunt type quarter-wave stub is shown. Microwave energy is applied to an input end 34 of a rectangular wave guide 36 which is shown in elevation with a narrow side toward the observer. A side arm 37 in the form of a rectangular wave guide, having its output working into a matched impedance, is shown rotated 30° from the normal position of a shunt T side arm. In this or any other position of rotation the energy abstracted

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from the guide 36 by the arm 37 is calculated by the previously mentioned equation

$$E=P \cos^2 \alpha$$

5 in which E is the energy abstracted by the guide 37, P is the energy applied to the guide 36 at its input terminal end 34, and α is the angle between the transverse axis of the arm 37 and the longitudinal axis of the wave guide 36. In order to match the arm 37 to the guide 36 an iris composed of two vanes 38 and 39 is applied to the arm 37 at the junction of the arm 37 and the guide 36. To prevent the appearance of an orifice between the arm 37 and the guide 36 when the arm 37 is at any angle other than zero, which would appear, as for instance in Fig. 2 at the positions 41 and 42, two metal ears 43 and 44 are fixed to the guide 36 beneath the arm 37. In these ears are machined suitable arcuate guide ways (not shown), and the arm 37 is mounted upon a turntable similar to that described in connection with Fig. 1, to rotate in the guide ways in the ears provided for it.

A quarter-wave shunt type short-circuited stub 46 is provided at a distance B from the arm 37 equal to an odd integer times one-quarter wavelength in the guide, to assist in matching the junction of the arm 37 and the guide 36. In order to maintain the phase of each part of the wave reflected from the quarter-wave arm 46 correct in relation to the analogous part of the arm 37, it is necessary to rotate the stub 46 in concert with the arm 37. This is accomplished by two gears 47 and 48 and a pinion 49 similar to those described in connection with Fig. 1, the pinion 49 being rotated by any means through its shaft 51. The mechanical construction of the base of the stub 46 and of the turntable on which it is mounted is similar to that described for the arm 37.

The output end terminal 52 of the guide 36 may be connected to an impedance-matched load, to which it delivers microwave energy, which for all adjustments of the pinion 49, is the difference between the energy supplied to the input terminal 34 and that abstracted by the side arm 37. Since all impedance matches may be made substantially perfect there is substantially no reflection toward the power source at any setting of the angular position of the side arm 37 and stub 46.

Fig. 3 illustrates another embodiment of the invention by which microwave energy may be controlled without rotating any input or output terminals. This embodiment utilizes series arms although shunt arms and stubs may be used instead.

Microwave power is applied by any means to one end 53 of a rectangular hollow wave guide 54 having a series side arm 57 connected to a second impedance-matched load at its terminal end 59. The side arm 57 is matched at its junction with the guide 54 by any conventional means such as by an inductive iris. In order to divert the microwave energy through the side arm 57 it is desired to provide an impedance varying means in the guide 54 beyond the side arm 57. To this end, a quarter-wave series stub 58 is connected to the guide 54 at a distance C beyond the side arm 57 equal to one-quarter wavelength in the guide, or an odd integer multiple thereof. The quarter wave stub 58 will, when in the series position across the broad face of the guide 54, cause total reflection at such phase as to cause all of the input energy to go

out of the side arm 57 and none to reach the terminal 56, in the manner previously described in connection with Fig. 1. If the stub 58 be mounted on a turntable similar to that described in connection with Fig. 1 and be rotated 90° about its own axis, from the position shown in Fig. 3 it will cause no reflection and will permit maximum output to be emitted from the terminal 56. At intermediate angle of rotational position the stub 58 will produce some reflection and will therefore act to produce adjustable division of microwave power between the output terminals 56 and 59. However, because the single stub 58 will cause aberrations in the standing wave and for intermediate positions of the stub 57 the voltage loop will occur at different points along the length and the breadth of the guide 54, it is preferable to provide an additional quarter wave stub 61 to reduce the effect of the voltage standing wave aberrations caused by the stub 58. The second quarter wave stub 61 is mounted on a turntable in a manner similar to the mounting of stub 58 at the same distance C from the axis of the arm 57. It may conveniently be placed in the broad face of the guide 54 opposite the stub 58 to have the same magnitude of reflective effect as the stub 58, so that the two stubs reinforce each other in their reflective effects. If the stub 61 be rotated simultaneously with the stub 58 but in the opposite sense about their common axis, the aberrations of the standing wave nodes in the guide 54 near its junction with the arm 57 will be completely eliminated, an aberration at any point caused by the stub 58 being exactly neutralized by an equal and opposite aberration caused by the stub 61. As a result, if the stubs 58 and 61 be so rotated, each through 90°, the microwave power output at the terminal 56 will be varied between full magnitude and zero without causing any reflection of energy toward the input end 53.

A convenient means of rotating the stubs 58 and 61 is provided by two bevel gears 62 and 63 attached respectively, to the stubs 58 and 61; the gears being meshed with bevel gear 64 which may be suitably journaled on the external wall of the guide 54 and may be actuated by any desired means. Rotation of the gear 64 will then turn the gears 62 and 63 through equal and opposite angles and with them the stubs 58 and 61.

This invention is capable of being applied to a microwave power divider having any number of output terminals to provide a convenient and efficient means for dividing the power among all of them in any proportions desired. This is illustrated in the embodiment of Fig. 4 comprising a hollow rectangular guide 66 shown in schematic form having plurality of outlets 68, 69, 71 and 72. The guide 66 may have any desired length, as indicated by the broken portion 67 and may have any desired number of series side arm outlets, of which only four, 68, 69, 71 and 72 are shown. The guide 66 has an end 73 to serve as an input terminal, the other end 74 serving as an additional output terminal. The output terminal 74 should be coupled to a matched or completely absorptive load so that there will be no energy reflection toward the input end 73. With each side arm 68, 69, 71 and 72 is associated a reflective stub 76, 77, 78 and 79, respectively, and all arms and stubs are mounted on turntables for axial rotation. Each arm and its associated stub are geared together

to rotate in unison and are controlled by a suitable manual control knob. To this end, control knobs 81, 82, 83 and 84 are provided. It will be readily apparent that the microwave energy can be diverted from the main guide 66 by adjusting the various control knobs. As in the previous embodiments suitable matching means are provided at the junctions between the side arms 68, 69, 71 and 72 with the main guide 66. These matching means are designed to prevent mismatching reflections when the side arms are in the series position, that is, when the broad faces of the side arms extend at right angles to the axis of the main guide 66. Since the reflecting stubs 66, 67, 78 and 79 are adapted to be rotated simultaneously with their respectively associated side arms, the effective mismatch between these side arms and the main guide 66, for the intermediate relative positions of the side arms is effectively neutralized.

It follows from the foregoing description that the present invention provides a novel microwave energy controlling device in which a main guide is provided which is capable of transmitting microwave energy in a predetermined plane of polarization and in which suitable side arms with appropriate matching means are connected to the main guide; the coupling between the main guide and the side arms being responsive to the relative position of the plane of polarization and the polarizing plane of the coupling means to control the diversion of microwave energy from the main guide into the side arms. One of the salient features of the present invention is the provision of means for accomplishing this division of microwave energy without at the same time disturbing the impedance of the load into which the generator or other source of high frequency energy is supplied.

What is claimed is:

1. A microwave power divider comprising, a rectangular hollow microwave guide having an input end terminal and an output end terminal, a second rectangular hollow microwave guide joined to said first-named guide to form therewith a side arm T junction, means to match the impedance of said junction for microwave energy applied to said input end terminal, a quarter-wave short-circuited rectangular hollow microwave guide stub joined to said first-named guide between said T junction and said output end terminal at a distance from said T junction equal to an odd multiple of a quarter wavelength of microwave energy in the guide, means to match the impedance of the junction of said stub and said first-named guide for microwave energy applied to said input end terminal, and means for adjustably rotating said stub about its own axis.

2. A microwave power divider comprising a first rectangular hollow microwave guide having an input end terminal and an output end terminal, a second rectangular hollow microwave guide joined to said first guide to form therewith a side arm T junction, means to match the impedance of said junction, a quarter-wave short-circuited rectangular hollow microwave guide stub joined to said first-named guide between said T junction and said output end terminal at a distance from said T junction equal to an odd multiple of a quarter wavelength of microwave energy in said guide, means to match the impedance of the junction of said stub and said first guide and means for adjustably rotat-

ing in concert said first guide and said stub about their respective axes.

3. A microwave power divider in accordance with claim 2 in which said side arm is of the series type and in which said stub is of the series type. 5

4. A microwave power divider in accordance with claim 2 in which said side arm is of the shunt type and in which said stub is of the shunt type.

5. A microwave power divider comprising, a 10 first rectangular hollow microwave guide having an input end terminal and an output end terminal, a second rectangular hollow microwave guide joined to said first guide to form therewith a side arm T junction, means to match the impedance of said junction, a first quarter-wave short-circuited rectangular hollow microwave guide stub 15 joined to said first guide between said T junction and said output end terminal on the same side thereof as said second guide, the distance of said first stub from said T junction being an odd multiple of a quarter wavelength in said guide, a second quarter-wave short-circuited rectangular hollow microwave guide stub joined to said 20 first guide between said T junction and said output end terminal on the side of said first guide opposite said second guide, the distance of said second stub from said T junction being an odd multiple of a quarter wavelength of microwave energy in said guides, means to match the impedances of the junctions of said first and second stubs with said first guide, and means for 25 adjustably rotating said first and second stubs in the same degree but in opposite directions about their common axis.

6. A microwave power divider comprising, a

first rectangular hollow wave guide capable of receiving microwave energy at one end and emitting energy at the other end, a second rectangular hollow microwave guide joined to said first guide to form a side arm T junction therewith, a first rectangular hollow guide quarter-wave short-circuited matched stub joined at a right angle to one side of said first guide and rotatable thereon about the axis of transmission of said stub, a second rectangular hollow guide quarter-wave short-circuited matched stub joined at a right angle to the opposite side of said first guide with the axis of transmission of said second stub aligned with the axis of transmission of said first stub, said second stub being rotatable upon said first guide about the axis of transmission of said stub, and means for adjustably rotating said first and second stubs in the same degree but in opposite directions each about their collinear axes.

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