

March 9, 1954

R. H. DICKE

2,671,883

WAVE GUIDE IMPEDANCE TRANSFORMER

Original Filed March 8, 1945

FIG. 1

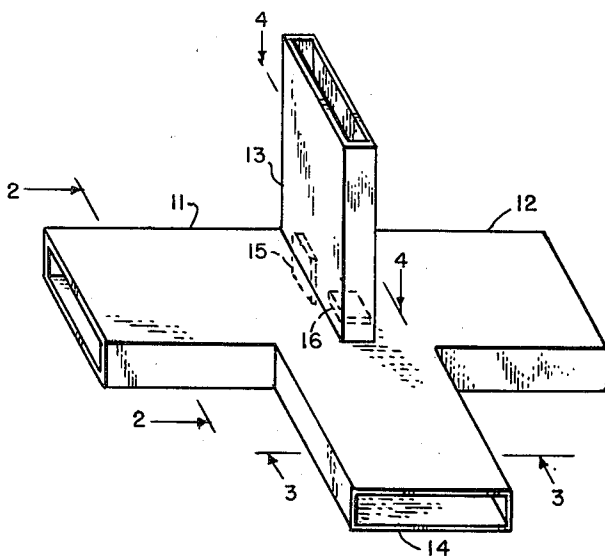


FIG. 2

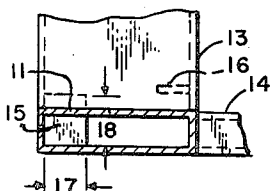


FIG. 3

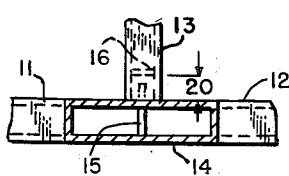


FIG. 4

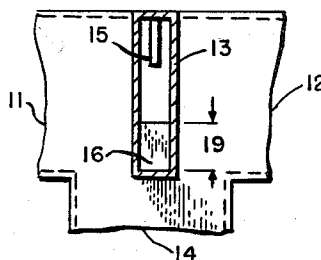


FIG. 5a

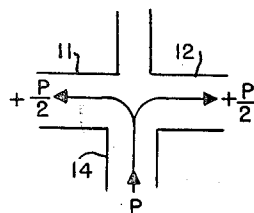


FIG. 5b

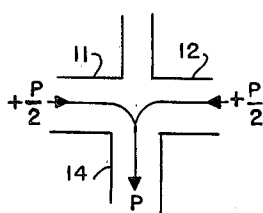


FIG. 5c

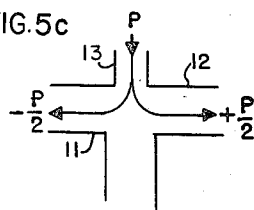


FIG. 5d

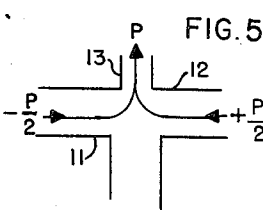
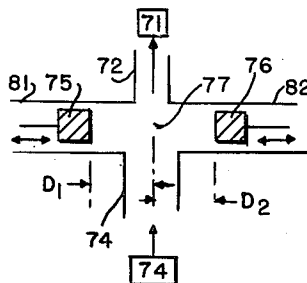


FIG. 6



INVENTOR.

ROBERT H. DICKE

BY

Harry M. Saragovitz
ATTORNEY

UNITED STATES PATENT OFFICE

2,671,883

WAVE GUIDE IMPEDANCE TRANSFORMER

Robert H. Dicke, Cambridge, Mass., assignor, by
mesne assignments, to the United States of
America as represented by the Secretary of the
Army

Original application March 8, 1945, Serial No.
581,695, now Patent No. 2,593,120, dated April
15, 1952. Divided and this application March
19, 1952, Serial No. 282,036

2 Claims. (Cl. 333—33)

1

This application is a division of application
Serial No. 581,695, entitled "Transmission Sys-
tems," which was filed March 8, 1945, and issued
April 15, 1952, as Patent No. 2,593,120.

This invention relates to transmission systems
and more particularly to an impedance trans-
former for use with ultra high frequency energy.

According to conventional theory the dominant
mode of operation of a wave guide may be defined
as that condition of operation in which the con-
figuration of electric and magnetic lines of force
permits the transmission of energy at the lowest
possible frequency through a wave guide of a
given size and geometric cross-section. It may
also be defined with equal accuracy as that con-
dition of operation in which the configuration of
electric and magnetic lines of force permits the
transmission of energy through the smallest
dimensional wave guide of a given cross-section
at a given frequency.

In a rectangular wave guide operated in the
dominant mode, there exists a sinusoidal distri-
bution of electric lines of force along the major
axis of the rectangular cross-section. These
electric lines of force or electric field vectors are
perpendicular to the major axis of the rectangle.

When a main rectangular wave guide designed
to be operated in the dominant mode is joined
symmetrically by a wave guide whose axis is par-
allel to the electric field vectors in the main wave
guide, the juncture is said to be a series junction.
When the joining wave guide is symmetrical to
a main wave guide and the axis of the joining
guide is perpendicular to the electric field vectors
within the main guide, the junction is said to be
a parallel junction. When these two junctures,
one series and one parallel, are made in such a
manner that the axes of the series and parallel
wave guides join the axis of the main wave guide
at the same point certain unique properties exist.
Broadly, any geometric arrangement of four wave
guide branches will also give these unique prop-
erties if the following conditions are met. The
axes of the four guides must meet at a common
point. In a first and second of these guide
branches the electric lines of force are perpen-
dicular to each other and the lines of force in one
of these first and second wave guide branches
must be perpendicular to a plane passing through
the axes of the first and second wave guide
branches. The third and fourth of these wave
guide branches must be symmetrical with respect
to the plane passing through the axes of the first
and second wave guide branches which was just
referred to. These unique properties are ex-
plained further in the detailed discussion of the

2

drawings. It will be appreciated, however, by
those skilled in the art that where any abrupt
change in structure occurs, mismatch and conse-
quent undesirable reflections also tend to occur.
This is especially so where one wave guide
branches into two or more wave guides. When
a wave guide is terminated in its characteristic
impedance, no mismatch or reflections will occur.
The desirability of the unique properties referred
to above render it advisable to eliminate the un-
wanted mismatch and reflections.

Many methods have been employed in the past
for matching or transforming one impedance to
another. At the lower radio frequencies this is
done with lumped circuits such as transformers
or with line stubs such as the double stub tuner.
For radio frequencies sufficiently high to warrant
the use of wave guides these stub tuners can still
be used but with increasing difficulty. Imped-
ance transformers with greater range of match-
ing and ease of operation are desirable.

One object of this invention is, therefore, to
terminate each wave guide at its junction with
other wave guides in its characteristic imped-
ance.

Still another object of this invention is to
match or transform one impedance into another.

In accordance with the present invention there
is provided a matched junction formed by three
wave guides. One of the three wave guides is
joined to a second of the three wave guides in a
series junction. The third wave guide joins the
second wave guide in a parallel junction. An iris,
for matching purposes, is inserted in the second
wave guide. It is mounted in such a position as
to lie in a plane which also contains the axes
of the first and third wave guides. A second iris
is located within the first wave guide. The two
irises are so adapted that each wave guide sees
as its termination at the junction its character-
istic impedance.

For a better and fuller understanding of the
invention, together with other objects thereof,
reference is made to the following detailed de-
scription taken in connection with the accom-
panying drawings in which:

Fig. 1 shows a improved wave guide junction;

Figs. 2, 3, and 4 show views looking into differ-
ent wave guides making up the junction of Fig. 1
to show the position of matching irises;

Figs. 5A, 5B, 5C, and 5D facilitate describing
some of the unique properties of the matched
junction shown in Fig. 1; and

Fig. 6 shows an improved impedance trans-
former.

Referring now more particularly to Fig. 1, there

is shown a matched junction formed by three wave guides. A first wave guide with two branches 11 and 12 is joined by a second wave guide 13, symmetrically in a series connection. A third wave guide 14 is joined symmetrically and in a parallel connection to the first wave guide 11—12. The series and parallel junctions are so made that the axes of the first, second, and third wave guides meet in a common point. Fig. 1 shows the wave guides 13 and 14 as being perpendicular to the wave guide 11—12. While this is a preferred embodiment, it is not desired to limit the invention here described to this geometric arrangement. Two irises 15 and 16, preferably in the form of thin plates of conducting material, are inserted at the junction to permit matching of all four wave guide branches, that is to say, looking from any one of the four wave guide branches toward the junction each of the wave guide branches will be terminated by its characteristic impedance. Fig. 2 shows the iris 15 partially closing off wave guide branch 11 as it is viewed from line 2—2 in Fig. 1. In Fig. 3 this same iris 15 is shown as it is viewed from line 3—3 in Fig. 1. Fig. 4 again shows the iris 15 as it is viewed from line 4—4 in Fig. 1. Figs. 2, 3, and 4 taken together show the iris 15 to be within the wave guide 11—12 and to lie in a plane which includes the axes of wave guides 13 and 14. By variation of the length 17 and the depth 18 of the iris 15 shown in Fig. 2, the iris 15 is adjusted empirically so that the third branch 14 is terminated in its characteristic impedance. Fig. 4 also shows the position of the iris 16. Figs. 2 and 4 taken together show the iris 16 to be within the wave guide 13. By variation of the length 19 of the iris 16 (Fig. 4) and the axial distance 20 of the iris 16 from the junction (Fig. 3), the iris 16 is adjusted empirically so that the second branch 13 is terminated in its characteristic impedance.

Referring now to Figs. 5A, 5B, 5C, and 5D specifically, there is shown four novel ways in which the matched junction of Fig. 1 operates. Although there are other novel modes in which a junction, such as is illustrated in Fig. 1, operates, the modes illustrated in Figs. 5A—5D inclusive are deemed sufficient for explanatory purposes. In Fig. 5A energy P, which enters the parallel connected wave guide 14, divides at the junction into the two branches 11 and 12 of main wave guide. The energy divides equally, and the two parts are in phase with each other as indicated by the designation $+(P/2)$ at the ends of each of wave guide branches 11 and 12. In Fig. 5B the converse of the condition illustrated in Fig. 5A is shown. If energies of equal magnitude and similar phase $+(P/2)$ enter the two branches 11 and 12 of the main wave guide, these energies combine at the junction, and all of this energy enters the parallel connected wave guide 14 and is designated by P. In Fig. 5C is shown the condition where energy P enters the series connected wave guide 13. This energy divides equally and passes into the two branches 11 and 12 of the main guide. The two energies will be in 180° phase opposition as shown by the designation $-(P/2)$ at the end of guide branch 11 and the designation $+(P/2)$ at the end of guide branch 12 in this figure. Fig. 5D shows the converse of the condition shown in Fig. 5C. If energies of equal magnitude and in 180° phase opposition as indicated by $-(P/2)$ and $+(P/2)$, the energies will combine and will all enter the series connected wave guide 13. This energy is

designated by P. To those skilled in the art, it will be obvious that energies which enter the two branches of the main guide but which are neither in phase nor in phase opposition will be combined and will divide going into both the series and the parallel connected wave guides. The relative division into the series and parallel connected wave guides will be a function of the phase relation existing between the two energies. This will be readily seen when one considers that either energy may be resolved into two components, one component in phase and one component in phase opposition to the other energy.

Fig. 6 shows a device employing a matched junction in a wave guide circuit as an impedance transformer. Because of the desirability of the matched junction, it is preferred for use in this circuit. However, the circuit will function with junctions like the one shown in Fig. 1 if the matching irises are omitted. The impedance 71 to be transformed is connected to a series connected wave guide 72 of a junction 77. The impedance 73 to which impedance 71 is to be transformed is seen when looking into a parallel connected wave guide 74. Two plungers 75 and 76 are inserted in wave guides 81 and 82 and are adapted to be adjusted in their relative positions. These two plungers are located at distances D_1 and D_2 , respectively, from the junction as shown in Fig. 7.

The method for determining the distances D_1 and D_2 is explained in the following part of the specification.

In a wave guide such as wave guide 72 which is terminated by an impedance 71, which is equal to Z_1 , other than its characteristic impedance Z_c there exists standing waves and associated therewith a standing wave ratio SWR. The SWR is defined as the ratio of the maximum amplitude of signal along the wave guide to the minimum amplitude of signal along the wave guides. The maximum and minimum amplitudes normally exist one fourth wavelength apart. If the impedance 71 or Z_1 is divided by Z_c , the resulting quotient which is a complex notation locates a point on an impedance circle diagram known as the Smith chart. A circle passing through this point with $1+j0$ as the center will describe the loci of all impedances existing along wave guide 72. Since we normally desire a matched system, we wish to transform Z_1 to Z_c . By variation of D_1 and D_2 it is possible to match any impedance Z_1 to the wave guide 72 i. e. to transform it to Z_c . D_1 and D_2 , the distances from the center of the T-junction to the plungers 75 and 76, can be thought of as being determined by two parameters X and Y which are functions of the two impedances Z_1 and Z_c considered. The following relation holds:

$$(1) \quad D_1 = X + Y$$

$$(2) \quad D_2 = X - Y$$

It is normally possible to calculate or determine experimentally the SWR. If the terminating impedance Z_1 and the characteristic impedance Z_c are known and both are pure resistances, then the reflection coefficient A is given by

$$(3) \quad A = \frac{Z_1 - Z_c}{Z_1 + Z_c}$$

and if the SWR is determined experimentally, the reflection coefficient A is given by

$$(4) \quad A = \frac{SWR - 1}{SWR + 1}$$

The following expression derived from a consideration of the junction described above gives a relationship between the reflection coefficient A and D_1 and D_2 .

$$(5) \quad A = \frac{1}{2} \left(1 + \cos \frac{4\pi(D_1 - D_2)}{\lambda} \right)$$

However, since from Equations 1 and 2

$$(6) \quad D_1 - D_2 = 2Y$$

Equation 5 may be solved for Y. From any arbitrary value of X, Y may be set by a system of levers arranged to move the two plungers 75 and 76 equally in opposite directions from the center of the junction 77 or Y may be set for each plunger separately. This will set up the proper SWR in the wave guide containing the impedance Z_1 . If now we vary X, we can effectively move the standing waves until the actual impedance Z_1 agrees with the value of the standing wave existing at the termination. Varying the parameter X can be thought of as rotating the Smith diagram or as effectively lengthening the wave guide between the point of matching and the terminating impedance Z_1 . A system of levers may be set up which will move the two plungers 75 and 76 in the same direction from the center of the junction and hence automatically set both plungers to conform to X.

It can be shown that any electrically symmetrical impedance transformer which will match any impedance to a wave guide will also match any impedance to any other impedance. As shown in the case above, if both plungers 75 and 76 are changed in position by the parameter Y, the SWR only is changed and the movement on the Smith chart is radial. If, however, we move only one plunger, the movement on the Smith chart will be circular. If we move the other plunger, we move along another circular path. It is possible, therefore, by altering the two plungers individually to transform any impedance to any other.

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

I claim:

1. An electrical apparatus for transforming a first impedance to a second impedance, said apparatus comprising pipe wave guide means having first, second, third, and fourth branches, said first, second, third, and fourth branches being so joined that their axes meet in a common junction point, said first and second branches having

a common axis and extending respectively in opposite directions from said common junction point, whereby said first and second branches form a main pipe wave guide, said third branch being series connected to said main wave guide, and said fourth branch being parallel connected to said main wave guide; a first iris inserted in said main wave guide in a plane containing axes of said third and fourth branches; a second iris inserted in said third branch, said first and second irises being adapted to cause each of said first, second, third and fourth branches to be terminated at the common junction point in its own characteristic impedance; a first movable shorting member inserted in and terminating the open end of said first branch; a second shorting member inserted in and terminating the open end of said second branch; said first impedance terminating the open end of one of said third or fourth branches; and means coupled to said first and second movable shorting members for positioning said first and second movable shorting members to predetermined distances from the center of said junction for obtaining said transformed second impedance at the open end of the other of said third or fourth branches.

2. An electrical apparatus for transforming a first impedance to a second impedance, said apparatus comprising pipe wave guide means having first, second, third, and fourth branches, said first, second, third, and fourth branches being so joined that their axes meet in a common junction point, said first and second branches having a common axis and extending respectively in opposite directions from said common junction point, whereby said first and second branches form a main pipe wave guide, said third branch being series connected to said main wave guide, and said fourth branch being parallel connected to said main wave guide; a first movable shorting member inserted in and terminating the open end of said first branch; a second shorting member inserted in and terminating the open end of said second branch; said first impedance terminating the open end of one of said third or fourth branches; and means coupled to said first and second movable shorting members for positioning said first and second movable shorting members to predetermined distances from the center of said junction for obtaining said transformed second impedance at the open end of the other of said third or fourth branches.

ROBERT H. DICKE.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,410,840	Samuel	Nov. 12, 1946
2,445,895	Tyrrell	July 27, 1948