Feb. 24, 1953 N. I. HALL ET AL 2,629,773

PHASE ADJUSTER

Filed Jan. 11, 1946 2 SHEETS--SHEET 1

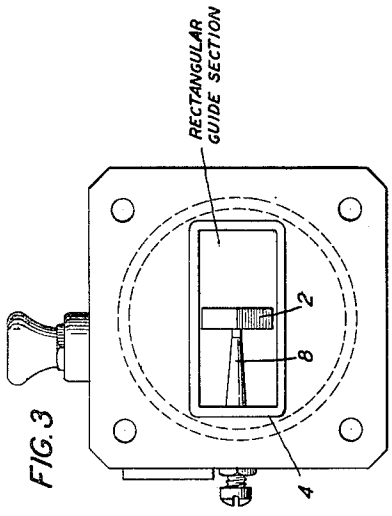

FIG. 3

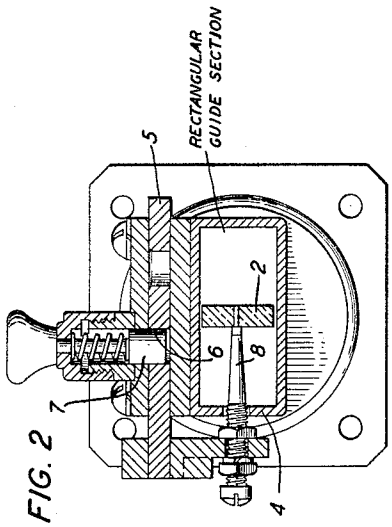

FIG. 2

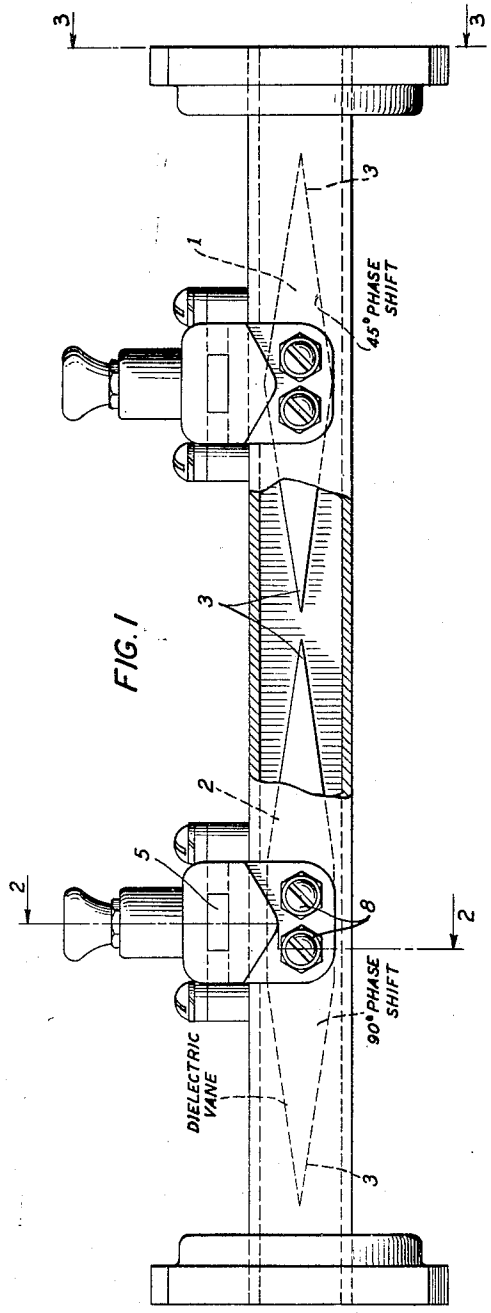

FIG. 1

INVENTORS: N. I. HALL
C. A. WARREN
BY
N. A. Ewing
ATTORNEY

Feb. 24, 1953 N. I. HALL ET AL 2,629,773

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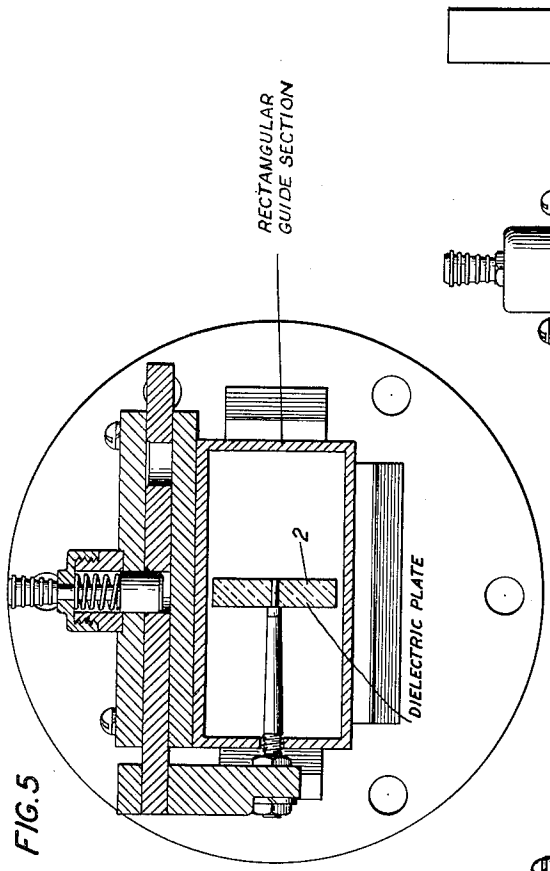

FIG. 5

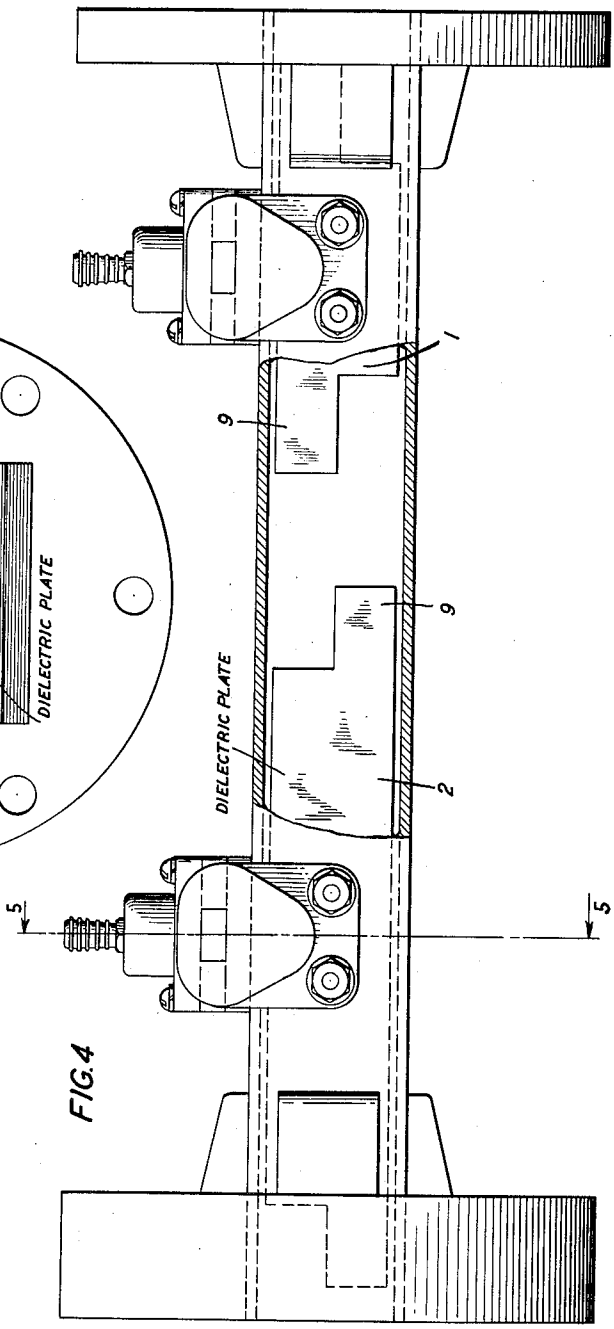

FIG. 4

INVENTORS: N. I. HALL
C. A. WARREN
BY
N. D. Ewing
ATTORNEY

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UNITED STATES PATENT OFFICE

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PHASE ADJUSTER

Nathan I. Hall, Madison, and Clifford A. Warren, Watchung, N. J., assignors to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application January 11, 1946, Serial No. 640,496

2 Claims. (Cl. 178—44)

1

This invention relates to the transmission of high frequency electromagnetic waves and more especially to wave guide phase shifters.

A prinicipal object of the invention is to minimize undesirable reflection effects in a microwave transmission system.

A further and more particular object is to provide an improved adjustable phase shifter that gives rise to a minimum of wave reflection under all operating conditions.

Phase shifters characterized by a fixed section of rectangular guide and a relatively movable metal or dielectric plate to provide a continuously increasing phase shift as the plate is moved from the side wall to the center of the wave guide, have heretofore been disclosed in the United States application D. H. Ring, Serial No. 640,495, filed concurrently herewith.

Difficulty has sometimes been experienced in obtaining a low standing wave ratio in certain critical positions of the plate and/or at certain frequencies. As the plate is adjusted from the side wall of the guide where it has negligible phase shift to the central region where it has a maximum phase shift, large standing wave ratios may be encountered.

In accordance with an embodiment of the invention there is provided a substantially reflectionless dielectric plate which may be projected in one jump from the side wall of the rectangular guide section into the central region thereof where the phase shifting effect of the plate is maximum, and which is so proportioned as to produce substantially no reflection when it is in the central region. A plurality of such plates, designed to introduce mutually different phase shifts when in the central region, are spaced apart along the guide so that by using various combinations of the plates a series of different values of phase shift may be obtained. In accordance with a feature of the invention, the supporting elements for the various plates, which elements individually tend to give rise to wave reflection, are so spaced apart that the resultant wave reflection is a minimum.

The nature of the invention and its various features, objects and advantages will appear more fully on consideration of the embodiments, illustrated in the accompanying drawing.

Referring to the figures of the drawing:

Fig. 1 is an elevation of a phase adjuster unit;

Fig. 2 is a cross-section thereof taken along line 2—2;

Fig. 3 is an end view thereof;

2

Fig. 4 is an elevation view of a modification of the phase adjuster; and

Fig. 5 is a cross-section thereof taken on line 5—5.

The phase adjuster shown in Figs. 1 and 2 comprises a section of rectangular guide having dielectric plates, or vanes 1, 2 of polystyrene therein that are adapted to be projected from the side wall 4 to the central region and vice versa.

The dielectric plates 1, 2 are each shaped and dimensioned to provide a predetermined phase shift, such as 45 degrees, 90 degrees, etc., effective only when the plates are positioned in the central region of the guide section. At the side walls, the dielectric plates 1, 2 have a negligible or zero phase shift effect.

Plate 1 per se, as illustrated in Fig. 1 is shorter and provides a 45-degree phase shift, while plate 2 provides a 90-degree phase shift, when separately positioned in the central region of the guide section. Impedance matching terminations 3, 3 of tapered form as illustrated in Fig. 1 or quarter-wave transformer, notched form as illustrated in Fig. 4 are provided at the ends of the phase shifting plates in the manner disclosed in the United States application of W. A. Tyrrell, Serial No. 590,365, filed April 26, 1945 which issued as United States Patent No. 2,546,840, March 27, 1951 and D. S. Ring, Serial No. 640,495, filed concurrently herewith.

Four discrete values of phase shift may be obtained from a pair of dielectric plates 1, 2, to wit, 0 degree, 45 degrees, 90 degrees, 135 degrees. Thus, when both plates are pulled over to the conductive side wall 4 of the guide section, the phase shift is substantially zero. When the shorter plate 1 is pushed into the central region of the guide, a phase shift of 45 degrees is produced. When the longer plate 2 is independently pushed into the central region, it provides a 90-degree phase shift. When both plates 1, 2 are simultaneously pushed into the central region, an additive phase shift of 135 degrees results. The particular values of phase shift herein disclosed are exemplary and therefore not intended as limitations on the scope of the invention.

Whereas the aforementioned impedance matching terminations on a single phase adjusting plate render it reflectionless, each plate has a pair of rod supports which may tend to set up undesirable reflections. To counteract and neutralize such disturbing effects, the individual supporting rods 8 on each plate are pref-

erably spaced apart a quarter wavelength whereby a mutual cancellation of the reflections results. Here, the wavelength in question is the wavelength in the guide section with the dielectric plates positioned in the central region of maximum field strength. The phase adjuster as a unit thereby is rendered substantially reflectionless.

The mechanical structure for projecting each dielectric plate 1, 2 from the side wall 4 of the guide section into the central region and back again is illustrated in Figs. 2 and 5. It comprises a manually slidable plate 5 with two openings 6 spaced apart a distance corresponding to the spacing between the side wall 4 and central region of the guide section. A spring pressed plunger 7 is adapted to selectively fit into the openings 6 and lock the slidable plate in either of the two positions of adjustment, corresponding to the two operative positions for the plate 2, namely, the side wall and central region. The vane 2 and its supporting rods 8 are rigidly connected to slidable plate 5 as shown in Fig. 2.

Figs. 4 and 5 illustrate a modified phase adjuster unit adapted for a different frequency band essentially similar to that shown in Fig. 1, except that quarter wavelength, notched, impedance matching terminations 9 are provided on the dielectric phase shifting vanes 1, 2 in lieu of tapered terminations, as more fully disclosed in the United States application of W. A. Tyrrell, Serial No. 590,365, filed April 26, 1945, which issued as United States Patent No. 2,546,840 March 27, 1951.

What is claimed is:

1. A reflectionless microwave phase shifter comprising a low-loss section of uniform hollow wave guide of closed rectangular cross-section through which a high frequency wave is guided in the dominant mode with the electric vector parallel to the narrower side walls of the guide, a low-loss dielectric vane of predetermined length for providing a predetermined phase shift, supporting means for maintaining said vane in a position lengthwise of said guide section and parallel to said narrower side walls, means for selectively moving said vane in one jump from one of said narrower side walls to the median plane of said section where the electric field vector is maximum, said vane having at its extremities a pair of integral terminals shaped to match the impedance that the guide section containing said vane has when said vane is in said median plane with the characteristic impedance the hollow guide section would have in the absence of said vane, said supporting means comprising a pair of rods retractably mounted in and perpendicular to said one side wall and attached at their inner ends to said vane, the spacing lengthwise of said guide section between said rods being a quarter of the wavelength said waves have when said vane is located in said median plane and a

locking means for said vane comprising a manually slidable plate mounted on said wave guide and connected rigidly to said rods and vane, said plate having two openings spaced apart a distance corresponding to the spacing between said side wall and median plane, and a plunger adapted to selectively fit into said openings.

2. A composite phase shifter for microwaves, comprising a section of low-loss uniform, hollow wave guide of closed rectangular cross-section throughout its length, a plurality of low-loss dielectric vanes of predetermined length, each providing a predetermined phase shift to dominant mode waves, supporting means for maintaining said vanes lengthwise of said guide and parallel to its narrower side walls, means for selectively moving said vanes in one jump from said side wall to the median plane of said section where the electric field vector is maximum, to provide a composite phase shift without introducing reflection, each vane being provided at its extremities with a pair of integral terminals shaped for impedance matching, said supporting means comprising pairs of rods retractibly mounted in and perpendicular to said side wall and attached to said vanes, the spacing lengthwise of said guide section between a pair of rods being a quarter of the wavelength which said waves have when said vanes are in the median plane and locking means for each vane comprising a plate slidably mounted on said wave guide and connected rigidly to said rods and vane respectively, each plate having two openings spaced apart a distance equal to the spacing between said side wall and median plane, and a spring pressed plunger adapted to selectively fit into said openings and maintain said vanes locked in the median and side wall positions respectively.

NATHAN I. HALL.
CLIFFORD A. WARREN.

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