

[54] MICROWAVE REPEATER

[72] Inventor: Manlio G. Abele, Garden City, N.Y.

[73] Assignee: General Applied Science Laboratories, Inc., Westbury, N.Y.

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[51] Int. Cl. H04n 3/36, H04n 3/60

[58] Field of Search 325/1, 14, 51; 333/95 S

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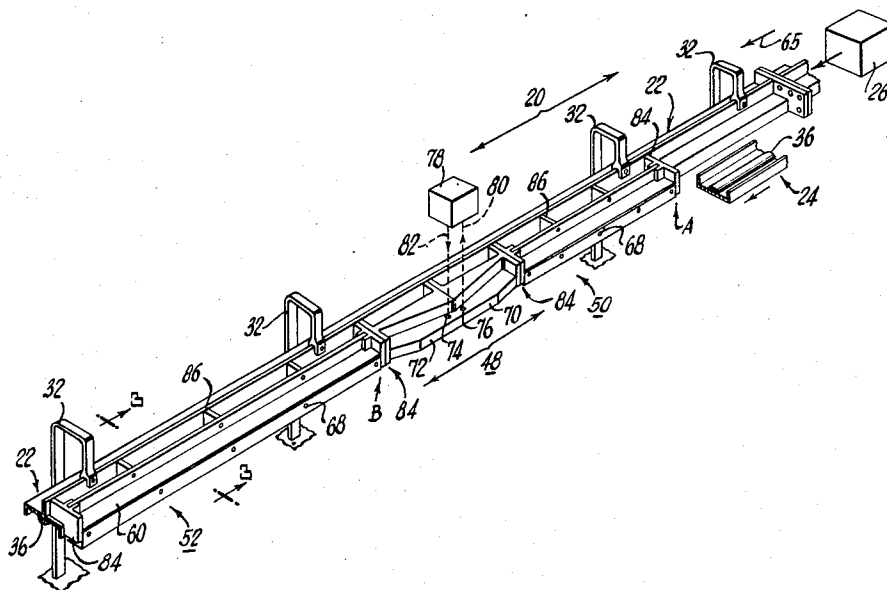
Primary Examiner—Robert L. Richardson
Attorney—Curtis, Morris & Safford

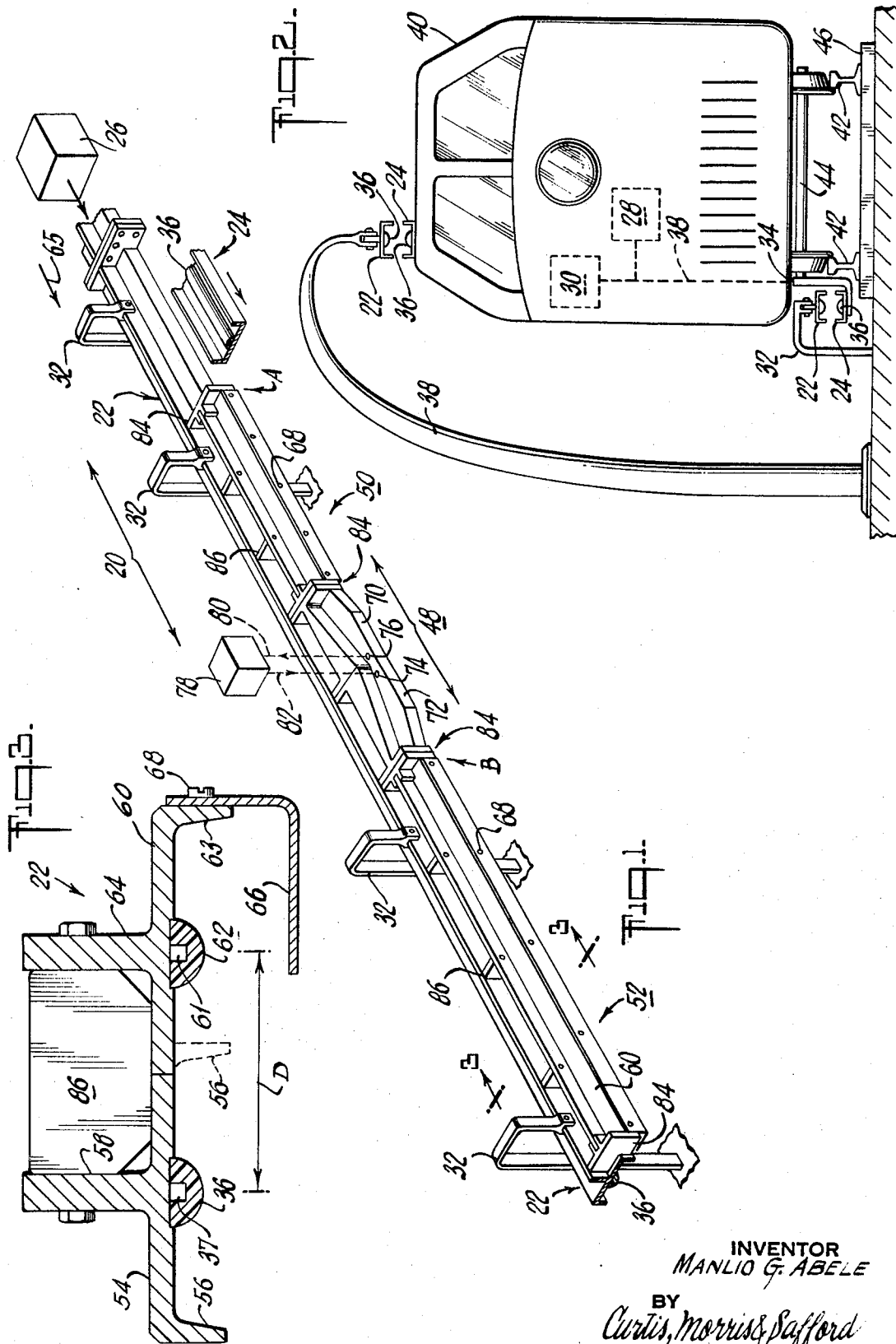
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ABSTRACT

A repeater for a stationary waveguide in a system for communicating between the waveguide and a moving vehicle such as a train. The stationary waveguide structure includes an inverted channel-shaped shield with a semi-cylindrical dielectric rod which acts as the waveguide. The shield protects the waveguide from ice, rain, birds and foreign objects, without itself interfering with the transmission of microwave energy through the waveguide. A coupler or antenna is attached to the moving vehicle and moves along underneath the stationary waveguide structure to couple signals between the vehicle and the stationary waveguide. The repeater comprises two short auxiliary sections of waveguides which are mounted parallel to the stationary waveguide, and a microwave amplifier. The first auxiliary waveguide removes a small portion of the signal flowing in the main waveguide and conducts that signal to the amplifier. The amplifier amplifies the signal and delivers it to the second waveguide which couples the energy back to the main waveguide in amplified form. By means of this repeater, the energy in the main waveguide is amplified substantially without interrupting the signal received by or transmitted by the moving vehicle.

17 Claims, 6 Drawing Figures





INVENTOR
MANLIO G. ABELE

BY
Curtis, Morris & Safford
ATTORNEYS

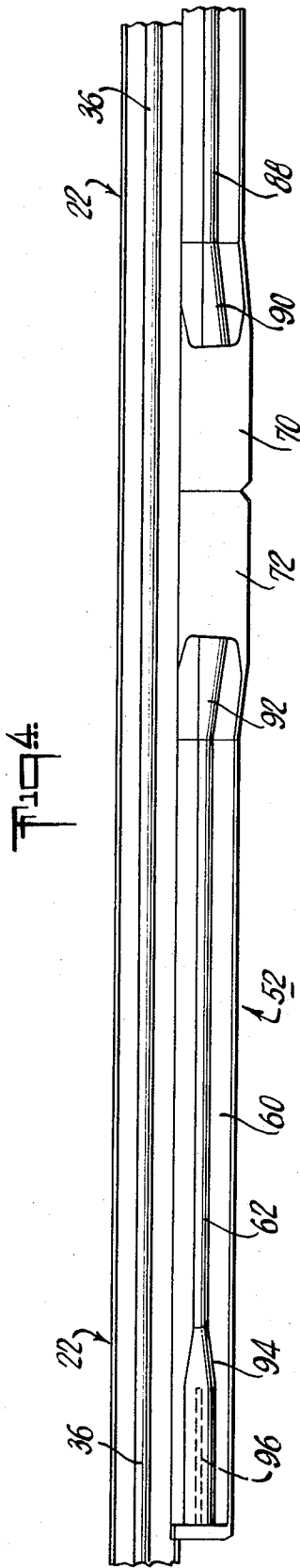


Fig. 5.

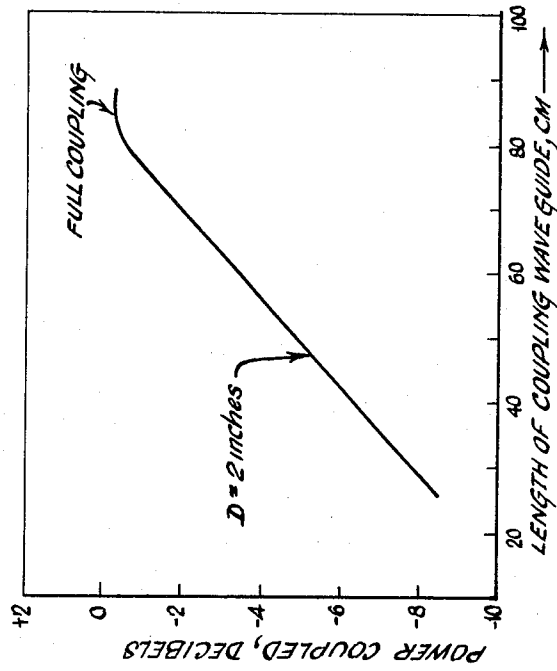
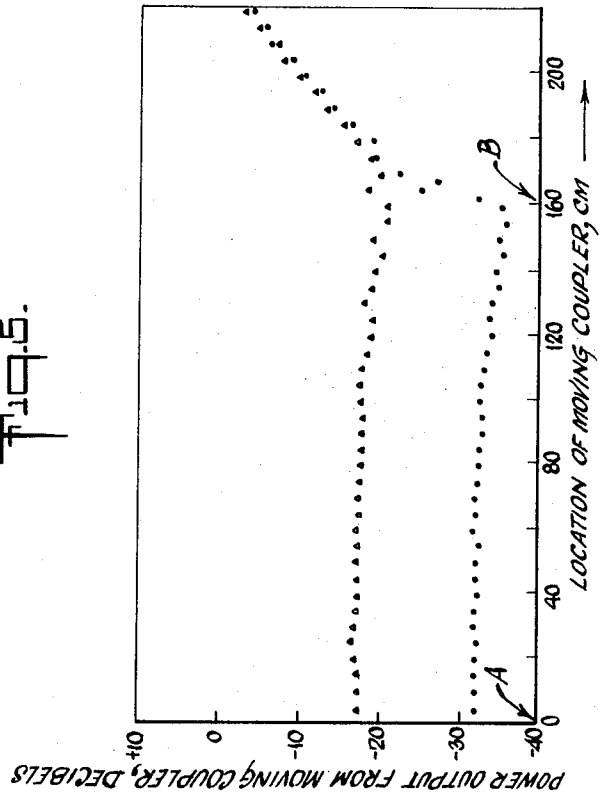


Fig. 5.



INVENTOR
MANLIO G. ABLE

BY
Curtis, Morris & Safford
ATTORNEYS

MICROWAVE REPEATER

This invention relates to repeaters for microwave transmission systems and particularly to repeaters for systems for microwave communication between a stationary waveguide and a moving body.

My co-pending U. S. Patent application Serial No. 803,621 filed March 3, 1969, now U. S. Patent No. 3,609,675, describes a particularly advantageous system for microwave communication between a stationary waveguide and a moving body such as a train. The present patent application describes a repeater which is particularly useful in such a system.

A major object of the present invention is to provide a repeater which will amplify signals transmitted over a waveguide efficiently and substantially without interrupting the microwave signals at or near the repeater station. Furthermore, it is an object to provide a repeater structure which is relatively simple, easy to maintain, and is relatively free from adverse effects which might be caused by adverse environmental conditions such as ice, snow, birds or other objects coming in contact with the waveguide.

The foregoing objects are met, in accordance with the present invention, by the provision of a microwave repeater consisting of an amplifier and a pair of auxiliary waveguide sections aligned near the main waveguide. One of the auxiliary waveguides removes a small portion of the signal from the main waveguide and delivers that portion to the amplifier. The amplifier delivers the amplified signal to the second auxiliary waveguide which couples the amplified signal back to the main waveguide. Preferably, the coupling device or antenna on the moving body is located considerably farther from the main waveguide than are the two auxiliary waveguides of the repeater.

The foregoing and other objects and advantages will be described in or apparent from the following description and drawings:

In the drawings:

FIG. 1 is a perspective, partially schematic view of the preferred embodiment of the present invention;

FIG. 2 is a schematic diagram showing the use of the system of the present invention in communicating with a moving vehicle;

FIG. 3 is a cross-sectional view taken along line 3—3 of FIG. 1;

FIG. 4 is a plan view of the under surface of the structure shown in FIG. 1; and

FIGS. 5 and 6 are graphs showing certain operational parameters of the present invention.

The communications system in which the repeater of the present invention is used is described in detail in my above-identified co-pending U. S. application Serial No. 803,621, now U. S. Patent No. 3,609,675, and the disclosure of that application is incorporated herein by reference. However, for the sake of convenience and clarity, a brief description of that communication system will be given.

The communication system, indicated generally by reference numeral 20 in FIG. 1, includes a stationary waveguide structure 22 and a moving coupling device or antenna 24 which, as is shown in FIG. 2, is attached to a moving body with which communication is desired. FIG. 2 shows the use of the system in communicating with a locomotive 40 of a railroad train. The stationary waveguide structure 22 is supported near the railroad tracks 42 by a plurality of support arms 32. The moving coupler or antenna 24 includes a length of waveguide of the same shape as the waveguide structure 22, and is positioned at a distance beneath the stationary waveguide 22 to receive and transmit signals between the stationary waveguide and the train. The coupler 24 can be suspended from the carriage of the vehicle by a support structure 34, or it can be positioned on the upper surface of the vehicle body, as also is shown in FIG. 2. In the later case, the stationary waveguide structure 22 is suspended from a plurality of relatively tall support arms 38. A transmitter 28 and a receiver 30 are located in the train and are connected to the coupling device 24 by means of a cable which is indicated at 38.

As is explained in greater detail in my above-identified co-pending patent application, the stationary waveguide structure 22 includes a conductive shield 54 with downwardly-extending flanges 56 (see FIG. 3). Secured to the shield between the flanges 56 is a semi-cylindrical dielectric rod 36 which is the waveguide. A square, centrally-located bore 37 is provided in the rod 36. A ridge or flange 58 extends upwardly from the center of the shield 54, and the stationary support arms 32 are fastened to the ridge 58. The shield 54 and the downwardly-extending flanges 56 protect the waveguide 36 from contact with snow, ice, birds, etc., which might adversely affect the transmission of energy through the waveguide. The structure of the coupling device or antenna 24 is substantially identical to that of the main waveguide except, of course, that separate means are provided for conducting microwave energy into or out of the coupler. Various arrangements for this purpose are described in my above-identified co-pending patent application.

Although the stationary waveguide structure described above and in my co-pending patent application conducts signals with relatively low attenuation, as with any waveguide which extends for a distance of several miles, repeater stations should be provided at various intervals along the length of the main waveguide in order to periodically amplify the attenuated signal to a suitable level. A particularly advantageous structure for such a repeater is shown in FIGS. 1, 3 and 4.

The repeater, which is indicated generally at 48, includes two relatively short auxiliary waveguide structures which are indicated at 50 and 52 in FIG. 1. Additionally, a conventional microwave amplifier 78 is provided. The first auxiliary waveguide 50 and the second auxiliary waveguide 52 both are positioned parallel and close to the main waveguide 36. The first auxiliary waveguide 50 extracts a small portion of the signal from the main waveguide and delivers it through a transition device 70, an outlet opening 76, and a conventional waveguide 80, to the amplifier 78. The amplifier 78 amplifies the signal, delivers the amplified signal through another guide 82, a hole 74, and another transition device to the second auxiliary waveguide structure 52. The second waveguide couples the amplified signal back to the main waveguide 36.

As it is shown in FIG. 3, the auxiliary waveguide structure 52 includes a shield 60 which is joined edge-to-edge with shield 54 of the main waveguide, and a central semi-cylindrical dielectric rod 62. The flange 56 is shown only in dashed outline because it has been removed to permit direct coupling between the waveguides 36 and 62. An upwardly-extending ridge 64 which is identical to the ridge 58, and spacer blocks 86 and bolts are used to fasten the two waveguides together in side-by-side relationship.

Shield 60 has a downwardly-extending flange 63 to which is attached an L-shaped metallic shield plate 66 by means of screws 68. The coupler 24 is positioned directly beneath the waveguide structure 22, at a distance substantially greater than the distance "D" separating the centerlines of the two waveguides 36 and 62. The shield 66 minimizes the amount of coupling from the waveguide 62 to the coupler 24.

The structure shown in FIG. 3 takes advantage of the fact that efficient coupling of energy to and from the waveguide 36 can take place at any point within a region extending for 180° about the midpoint of the diameter of the waveguide 36. That is, not only can energy be coupled to and from the coupler 24 which is located directly beneath the waveguide structure 22, but it also can be coupled quite effectively by means of another waveguide positioned in the same horizontal plane with the main waveguide.

The cross-section of the first auxiliary waveguide 50 is substantially identical to that of the second auxiliary waveguide 52, and is not repeated in the drawings.

In operation, microwave energy travels in the direction indicated by the arrow 65 in FIG. 1. Energy is coupled from the stationary waveguide 36 to the first auxiliary waveguide 50. The waveguide 36 operates in the hybrid HE₁₁ mode, and at a velocity which is less than the speed of light. Preferably, the ratio of the speed of light to the velocity of the waves is 1.01 or

1.02. Thus, the waves are surface waves. Therefore, coupling between the waveguides is not by radiation, but by means of electrical induction.

Preferably, only a relatively small portion of the energy from the main waveguide is extracted by the first auxiliary waveguide 50. For example, typically the energy of the main waveguide will be reduced by only 3 decibels due to the extraction. Thus, the signal energy remaining in the waveguide is substantially uninterrupted and will appear to be substantially continuous along the length of the first auxiliary section, and, in fact, along the whole length of the repeater.

The transition devices 70 and 72 are of a construction described in detail in my above-identified co-pending patent application. Their purpose is to smoothly match the semi-cylindrical waveguides to conventional waveguides of rectangular cross-section for coupling with the amplifier 78.

The signal from the first auxiliary waveguide 50 is amplified by the amplifier and delivered to the second auxiliary waveguide 52. Waveguide 62 is substantially longer than waveguide 50 in order to insure that substantially all of the energy in waveguide 62 is coupled into the main waveguide 36, and that substantially all of the energy in waveguide 36 is transferred to the waveguide 62.

As is shown in FIG. 4 (in which the shield 66 is not shown), the waveguide 62 has, at its trailing end, an enlarged portion 94 in which is embedded a wedge-shaped segment 96 of carbon absorbing material which absorbs substantially all of the microwave energy which reaches it. Thus, the energy coupled from the stationary waveguide 36 to the second auxiliary waveguide 62 is substantially completely absorbed by the absorber 96. As a result, only the amplified signal continues to travel along the main waveguide 36.

Although it is not shown in the drawings, there is an absorber structure identical to the structure 94, 96 at the lead end of the first auxiliary waveguide 50. This absorber absorbs unwanted reflected waves which travel in a direction opposite the direction of the energy traveling in the main waveguide.

FIG. 5 is a graph illustrating operational parameters of a device such as that shown in FIGS. 1, 3 and 4 which has been built and successfully tested. The power output values were measured by moving a coupler or antenna 24 beneath the waveguide structure in the direction of the arrow 65 in FIG. 1, and measuring the output signal from the coupler 24. The zero decibel level is that to which it is desired to amplify the signal in the main waveguide. The location of the moving coupler as it moves relative to the stationary waveguide and the repeater is plotted horizontally in FIG. 5. The point "A" (zero centimeters) is the point, shown also in FIG. 1, at which the leading edge of the coupler 24 is directly beneath the leading edge of the first auxiliary waveguide structure 50 as it is shown in FIG. 1. It can be seen that the signal level in the main waveguide 36 is either 17 or 32 decibels below the desired value at that point. The two different curves are taken assuming two different values of amplification by the amplifier 78, either 20 decibels (the upper curve) or 35 decibels (the lower curve), both at a frequency of 8.9 Gigahertz.

The point "B" (160 centimeters downline from point "A") on FIG. 5 corresponds to the point at which the leading edge of the coupler 24 is directly beneath the leading edge of the secondary auxiliary waveguide structure 52 (see FIG. 1). As the coupler 24 moves from point "A" to point "B," it can be seen that the signal level decreases very gradually by a total of only about 3 decibels. This represents the power which is being removed by the first auxiliary waveguide. Then, when the coupler 24 reaches point "B," the second auxiliary waveguide starts feeding amplified signals back into the main waveguide, and the amplified signal in the main waveguide is now detected by the coupler. It can be seen that the signal level increases gradually until it approaches the zero decibel level desired after the coupler 24 has moved a considerable distance along the second auxiliary waveguide. Thus, there is no discontinuity in the power coupled between the coupler 24 and the main waveguide. This is highly desirable feature which

overcomes the shortcomings of certain prior repeater devices which create discontinuities in the signals.

FIG. 6 shows the relationship between the length of the auxiliary waveguide 50 or 52 verses the amount of power coupled to or from that waveguide, for a distance "D" between the waveguides 36 and 52 of two inches. It can be seen that substantially full coupling is reached when the waveguide length reaches about 85 centimeters, and that coupling falls off for waveguide lengths either greater or less than that length. Since substantially full coupling is desired for the second auxiliary waveguide 52, it is made approximately 85 centimeters in length. The length of the section 50 is considerably less, since considerably less coupling is desired, with the result that it is about 61 centimeters in length.

It is desirable that the coupler 54 be positioned at a distance substantially greater than the distance "D" separating the adjacent waveguide 36 and 62. A spacing of from about one to four times "D" is preferred. This minimizes direct coupling between the waveguide 62 and the coupler 24.

The above description of the invention is intended to be illustrative and not limiting. Various changes or modifications in the embodiments described may occur to those skilled in the art and these can be made without departing from the spirit or scope of the invention.

I claim:

1. In a microwave transmission system including a first elongated waveguide, a repeater comprising second and third waveguides positioned in coupling relationship to said first waveguide, and means for receiving microwave signals from said second waveguides, amplifying said signals, and delivering the amplified signals to said third waveguide for coupling to said first waveguide, said second waveguide being adapted to receive a relatively small portion of the energy transmitted through said first waveguide.

2. A repeater as in claim 1 in which said first waveguide receives from said third waveguide a relatively large portion of the energy transmitted through said third waveguide.

3. A repeater as in claim 1 in which said waveguides each comprise a semicylindrical rod of dielectric material and a conductive shield on the flat portion of the rod.

4. A first stationary elongated microwave waveguide structure having a conductive shield covering the upper surface of a semi-cylindrical dielectric rod, a repeater comprising second and third relatively short waveguide structures, each having a conductive shield covering the upper surface of a semi-cylindrical dielectric rod, and an amplifier, said second and third waveguide rods being mounted parallel and closely adjacent to said first waveguide rod at different longitudinal positions, with the shields of the various waveguide structures being joined together, said amplifier being connected to receive energy from said second waveguide, amplify said energy, and deliver the amplified energy to the third waveguide for coupling into the first waveguide.

5. Apparatus as in claim 4 in which said second waveguide rod has a length such that it extracts only a relatively small portion of the energy from the first waveguide, and said third rod has a different length such that there is substantially full coupling of energy between said third and first waveguides.

6. Apparatus as in claim 4 including an absorber at the leading end of said second waveguide to absorb reflected waves, and another absorber at the trailing end of said third waveguide to absorb signals received in said third waveguide from said first waveguide.

7. Apparatus as in claim 4 including, on each of the shields of said second and third waveguides, an auxiliary shield extending downwardly and for a distance beneath the waveguide structure.

8. A system for communication between a stationary waveguide and a moving body, said system comprising a first long stationary waveguide adjacent the path for the moving body, waveguide coupling means on said body, located at a distance from said first stationary waveguide, for receiving signals from said first waveguide, a repeater comprising

second and third waveguides positioned in coupling relationship to said first waveguide, and means for receiving microwave signals from said second waveguide, amplifying said signals, and delivering the amplified signals to said third waveguide for coupling to said first waveguide, said second waveguide being adapted to receive a relatively small portion of the energy transmitted through said first waveguide.

9. A system as in claim 8 in which said first waveguide receives from said third waveguide a relatively large portion of the energy transmitted through said third waveguide.

10. A system as in claim 8 in which said waveguides each comprise a semi-cylindrical rod of dielectric material and a conductive shield on the flat portion of the rod.

11. A system as in claim 10 in which said shields are flat and horizontal and are joined together edge-to-edge to form a protective roof over the waveguide rods.

12. A system as in claim 10 including support posts attached to the shield of the first waveguide.

13. A system as in claim 8 in which said second waveguide rod has a length such that it extracts only a relatively small portion of the energy from the first waveguide, and said third rod has a different length such that there is substantially full

coupling of energy between said third and first waveguides.

14. A system as in claim 8 including an absorber at the leading end of said second waveguide to absorb reflected waves, and another absorber at the trailing end of said third waveguide to absorb signals received in said third waveguide from said first waveguide.

15. In a microwave transmission system including a first elongated waveguide, a repeater comprising second and third waveguides positioned in coupling relationship to said first waveguide, said second and third waveguides being everywhere spaced from said first waveguide and parallel to said first waveguide over a substantial length, and means for receiving microwave signals from said second waveguide, amplifying said signals, and delivering the amplified signals to said third waveguide for coupling to said first waveguide.

16. A repeater as in claim 15 in which said second waveguide is adapted to receive a relative small portion of the energy transmitted through said first waveguide.

17. A repeater as in claim 15 in which said waveguides each comprise a semicylindrical rod of dielectric material and a conductive shield on the flat portion of the rod.

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