

June 14, 1949.

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2,473,274

ULTRA HIGH FREQUENCY COUPLING

Filed Aug. 15, 1944

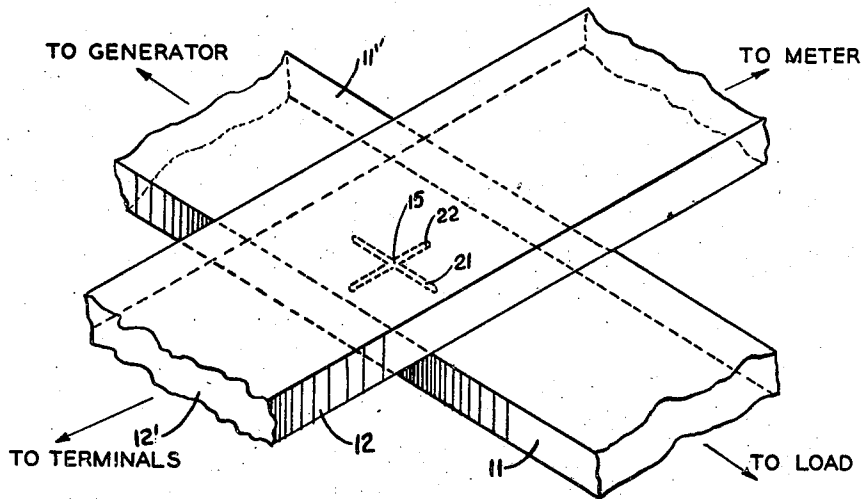


FIG. 1

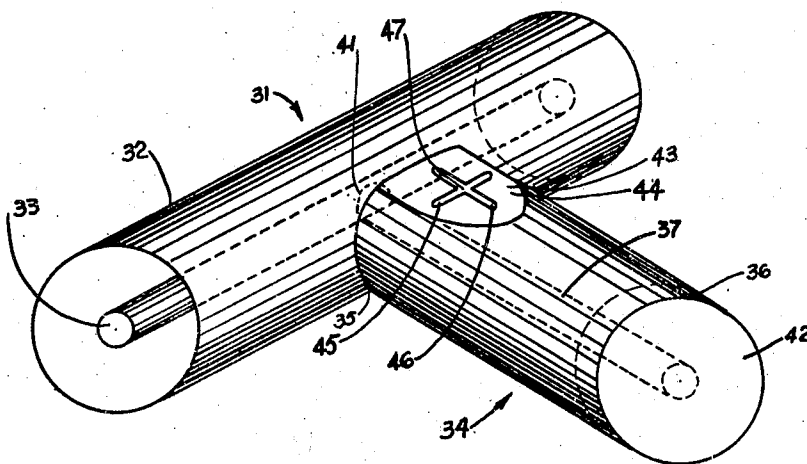


FIG. 2

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## UNITED STATES PATENT OFFICE

2,473,274

## ULTRA HIGH FREQUENCY COUPLING

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Application August 15, 1944, Serial No. 549,617

9 Claims. (Cl. 178—44)

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My invention relates in general to the field of ultra-high frequency transmission systems and more particularly concerns energy flow in wave guides.

Generally speaking, electromagnetic energy is propagated in wave guides in the form of traveling waves suitably initiated at a point in the guide. A non-directional launching unit within a wave guide will effect energy of equal magnitude to propagate in both directions within the wave guide to whatever terminations are located at the ends thereof. In general, however, it is particularly desirable that energy propagated within a wave guide be uni-directional and be delivered entirely to a load at a single end of the guide. Thus, directional means are utilized for propagating energy at one end of the guide which then travels down the guide to whatever termination appears at the other end.

In ultra-high frequency measurements, it is often desirable to know the amount of ultra-high frequency energy traveling along a transmission line or wave guide in only one direction, regardless of the presence of other energy traveling in the opposite direction. Thus, in controlling reflection from a load, measurement of the reflected energy only would enable adjustment of the load until no energy is reflected from the load.

I have discovered that energy may be coupled from one wave guide to another in such a manner that uni-directional traveling waves in the first guide produce uni-directional traveling waves in the second wave guide.

A single traveling wave in a wave guide has a current at the very center of the guide which is purely longitudinal. At the two side walls of the guide, the current is purely transverse, no longitudinal components existing at the side walls. At a particular cross section plane in the guide these two currents do not reach their maximum at the same instant, but are separated in phase by ninety degrees. For a wave traveling in one direction, the transverse current is ninety degrees ahead of the longitudinal current and for a wave traveling in the other direction, the transverse current is ninety degrees behind the longitudinal current. This provides a physical property of the wave which is different for the two different directions of propagations and which I employ in carrying out my invention.

In one form of my invention, a rectangular wave guide is juxtaposed with another rectangular wave guide of identical construction. The two are placed together with their axes at right

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angles and with their large dimension sides in contact.

The engaging surfaces of the two wave guides form a square. Along the diagonal of this square at some point between the center of the diagonal and one end, the transverse current of the first guide is substantially equal to the longitudinal current of the same guide. At this point, I cut two slots at right angles to each other in the common contacting faces of the two guides for coupling energy from one guide to the other. One of these slits is parallel to the transverse current and the other is parallel to the longitudinal current.

The coupling aperture thus formed should be of the shape of a small cross, the two slots forming it having a width comparable to or less than that of the guide wall thickness and being small compared with the wave length of the signal energy. This location, however, need not be exact because any error due to improper placement of the coupling aperture tends to cancel out because of the right angle relation of the two guides. The transverse current of the first guide is coupled only to longitudinal current of the second guide and the longitudinal current of the first guide is coupled only to the transverse current of second guide and by symmetry it is apparent that the cross couplings must also be equal provided the two guides are truly at right angles and the cross symmetrically constructed.

The longitudinal current and transverse current of the first guide produce a longitudinal and transverse current in the second guide and insofar as the currents in the second guide are in plus ninety degree phase relation, they will produce a propagated wave of circular polarization in the second guide in one direction. If they are in minus ninety degree phase relation, they would produce a wave in the opposite direction. Thus one direction of propagation in the first guide excites only one direction of propagation in the second guide.

If waves in both directions exist in the first guide, both waves would be produced in the second guide in the same proportion but in opposite directions. In that case, the second wave guide would have a wave starting from the coupling slots and traveling to the left due to the wave in one direction in the first guide and would have a wave starting from the coupling slots and traveling to the right in the second guide due to the wave traveling in the opposite direction in the first guide.

Precautions must be taken to prevent the trav-

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eling wave in the second guide excited by the unwanted wave in the first wave guide from rebounding from one end of the second wave guide and traveling backwards to the detector in the second wave guide. To this end, one end or both ends of the second wave guide must be terminated in a very good quality termination so as to be perfectly matched because otherwise energy reflected from this termination in large measure will reach the output detector, only a very small fraction of it passing back through the slot into the first wave guide.

My invention accordingly contemplates the transfer of energy from one wave guide to another through cross-slits of the type to be described. If these cross slits are located in a surface common to two wave guides with their axes at right angles, the direction of energy flow in the second wave guide will have a direction of travel which is a function of the direction of energy travel in the first wave guide. If the propagation within the first wave guide is in both directions, then the radiation within the second wave guide will also be in both directions.

The basic concept of radiation from a wave guide to cross slits may of course be applied to any type of wave guide configuration as for example wave guides of rectangular or circular cross-section.

It is therefore an object of my invention to provide means for coupling two wave guides so that uni-directional energy in one guide will produce uni-directional traveling energy in the other guide.

Another object of my invention is to provide a coupling between wave guides comprising cross slits in a common wall of the wave guide.

A further object of my invention is to provide cross slits in a common wall between two wave guides so that a single traveling wave in one guide will propagate a traveling wave in the other guide having a corresponding direction of travel.

Still a further object of my invention is to provide a novel and simple method of measuring the energy flow in a wave guide.

These and other objects of my invention will now become apparent from the following specification taken in connection with the accompanying drawings, in which

Figure 1 is a broken perspective view of two mutually coupled rectangular wave guides.

Figure 2 is a view of two coupled coaxial transmission lines.

Referring now to Figure 1, there is shown a pair of mutually perpendicular wave guides 11 and 12. The wave guides 11 and 12 are of substantially similar construction and are positioned so that the upper wall 11' of the wave guide 11 contacts the lower wall 12' of the wave guide 12 over a substantially square area.

If wave guide 11 is energized at one end thereof by a source, a uni-directional traveling wave will be propagated down the guide to whatever termination is provided at the other end thereof. In general, electromagnetic energy propagating down the wave guide 11 will result in current flow on the inner walls of the wave guide. The exact nature of the current flow on the inner surface of the guide is, of course, determined by the type of wave propagated therein. For example, most TE waves in rectangular wave guide will have both current flow parallel to the axis of the wave guide and perpendicular to the axis of the wave guide.

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The longitudinal and transverse current flow on the inner surface of a wave guide carrying a uni-directional traveling wave are always 90° out of phase. There exists spaced points within the wave guide 11 where the longitudinal and transverse currents in the metallic surface are equal in magnitude and 90° out of phase. As illustrated in Figure 1, a pair of mutually perpendicular slits have been cut into the upper surface 11' of the wave guide 11 having an intersection at point 15 along a diagonal of the square formed by the contacting walls of the two guides. These slits 21 and 22 which perpendicularly bisect each other at point 15 are arranged so that slits 21 intercept the transverse current in the wave guide 11, and slits 22 intercept the longitudinal current normally flowing on the inner surface of the upper wall 11'.

If now point 15 is located so that the longitudinal and transverse current thereat are equal in magnitude, then the current flow at the edges of slits 21 and 22 will be equal in magnitude but ninety degrees out of phase. Accordingly, during one quarter of the wave, the transverse current will be increasing while the longitudinal current is decreasing. During the next quarter cycle, the transverse current will be decreasing, while the longitudinal current will be increasing in the reverse direction. As is well understood, this type of current flow will result in an electro-magnetic field pattern of circular polarization.

The sense of rotation of the electro-magnetic field thus produced is of course dependent upon the direction of the longitudinal and transverse current flow at the edges of slits 21 and 22 respectively. This is in turn dependent upon the direction of energy flow within the wave guide 11, and accordingly the sense of the circularly polarized electro-magnetic field established at slits 21 and 22 will be a function of the direction of energy flow within wave guide 11.

The circularly polarized magnetic field established at the slits 21 and 22 will, if the slits are small as compared with a wave length, be radiated from wave guide 11.

As illustrated in Figure 1, wave guide 12, which intersects similar wave guide 11 at right angles, contains a symmetrically located pair of mutually perpendicular slits 21 and 22 which coincide with the corresponding slits in the upper wall 11' of the wave guide 11. In other words, the pair of slits 21 and 22 are cut into the common contacting surface between the wave guides 11 and 12. These slits in the two wave guides are of equal length where, as here, the two guides have their axes at right angles. Where the axes of the wave guides are paralleled, the slots are of unequal lengths unless their locations are carefully chosen.

In accordance with my invention, the electro-magnetic field of circular polarization established at the slits 21 and 22 as a result of current flow on the inner surface of wave guide 11 is radiated into the wave guide 12. Further, the radiation of waves of circular polarization through crossed slits of the type described will establish within the wave guide 12 a uni-directional traveling wave, the direction of which is a function of the rotational sense of the common electromagnetic energy. The traveling waves thus established in wave guide 12 will be propagated in a single direction to any suitable termination provided therefor. Thus by loading wave guide 12 with the correct terminating impedances at both ends, a single uni-directional wave in the first

guide will excite a uni-directional wave in the second guide so that power will be delivered to only one of the two terminations of wave guide 12.

Thus, summarizing the basic principles of my invention as illustrated in Figure 1, a uni-directional traveling wave established within a wave guide will result in longitudinal and transverse surface current within the wave guide, which are in phase quadrature. A pair of mutually perpendicular slits cut into a wall of the wave guide at a point where the longitudinal and transverse currents are equal will result in the establishment of a circularly polarized electromagnetic field which will radiate from the slits into surrounding space. Conversely, the application of a circularly polarized electromagnetic field to a wave guide at a point where mutually crossed slits are cut therein will result in a single traveling wave in the guide, the direction of which will be a function of the rotational sense of the applied circularly polarized waves. If the crossed slits which are small compared with a wave length of the propagated energy are located in the common wall between two mutually perpendicular wave guides, a single traveling wave in one will produce a corresponding single traveling wave in the other. A reversal of the direction of propagation of the traveling wave in the first wave guide will correspondingly result in a reversal of the energy propagation in the second wave guide.

This basic principle, as illustrated and described in connection with the crossed rectangular wave guides shown in Figure 1, may be applied to various other wave guide configurations.

As illustrated in Figure 2, a coaxial line 31 comprising an outer cylindrical shield 32 and a central concentric conductor 33 is fitted with a tuning stub 34 at an aperture 35 in the outer cylindrical shield 32 of the coaxial cable. The stub 34 comprises essentially a cylindrical shield 36 secured to the outer shield 32 of the concentric line 31, and an inner concentric conductor 37 which extends into coaxial line 31 and is joined at 41 to the inner conductor 33. A short circuiting metallic plate 42 seals the end of the stub 34. At the inner end of the stub support 34, the outer cylindrical shield 36 is machined flat at 43 to provide a substantially circular planed surface 44. The planed metallic surface 44 is cut to provide the slits 45 and 46 which perpendicularly bisect each other at point 47. The slit 45 is disposed parallel to the axis of the inner conductor 33 of the coaxial line 31, and the slit 46 is perpendicular to the inner conductor 33.

Ordinarily the propagation of a single traveling wave within the coaxial line 31 does not result in transverse current flow along the inner surface of the metallic shield 32. However, in the region of the stub support 34, as for example along the inner surface of the machined plate 44, both longitudinal and transverse surface current flow exist, and accordingly a circularly polarized electromagnetic field is established in the region of crossed slits 45 and 46. This field is radiated to the space surrounding the coaxial line 31. If a second coaxial line not shown in Figure 2 for clarity is provided with a similar stub and arranged with a pair of mutually perpendicular slits identical to slits 45 and 46, and is positioned so that the slits are in contact with slits 45 and 46 in a common wall, and, in addition, so that it is perpendicular to coaxial line 31 and its stub is perpendicular to the stub of the coaxial line, then the circularly polarizing electromagnetic field

radiated from slits 45 and 46 in the surface 44 of the stub support will enter the second coaxial line and establish therein a single traveling wave. This traveling wave will radiate in a single direction through the second coaxial line and will deliver energy to a suitable termination at one end thereof.

Reversal of the direction of propagation within coaxial cable 31 will correspondingly cause reversal of the propagation direction in the second coaxial line contacting at stubs 34.

It will now be apparent that this arrangement may be used in observing the reflection from a load. A suitable measuring device, such as wattmeter, is connected at one end of wave guide 12 and a correct termination for absorbing energy is mounted in the other end of the wave guide 12. Both the detector or wattmeter and the termination are made good energy absorbers so that there is no reflection from either. Any reflected energy in the wave guide 11 will in accordance with the device here described excite a wave in wave guide 12 in a predetermined direction.

Assuming that the reflected energy in wave guide 11 coming from a load at one end of the wave guide 11 excites a wave flowing toward the left in wave guide 12, a meter mounted at the right end of wave guide 12 will measure this reflected energy. The load in wave guide 11 may now be adjusted until the reflected energy is zero, as will be indicated by the meter in wave guide 12.

The energy from the source coming from the opposite direction in wave guide 11 will in that case flow to the left in wave guide 12. This energy is absorbed by the termination to the left of wave guide 12 and therefore does not interfere with the reading of the meter at the right of wave guide 12. If it is desired to measure the energy flowing from the source, it is only necessary to switch my novel unit comprising the intersecting wave guides 11 and 12 through 180° so that it is connected to the source of energy in the same sense as it was in the previous example connected to the load. Energy from the source will in that case excite a flow of energy in wave guide 12 toward the meter and any reflected energy from the load will excite a wave toward the absorption device in wave guide 12.

To this end my unit, such as shown in Figure 1, is provided with suitable fittings which enables coupling it to the main wave guide over which energy is being delivered and which is to be measured by my device. By disconnecting the fittings, the unit may be switched in any desired sense to the wave guide to effect corresponding coupling thereto for measuring either the energy from the source or from the reflector.

In another case, in the ordinary types of field strength indicating devices used in connection with such measurements, particularly wattmeters, the reflected wave often causes large errors in reading by adding to or subtracting from the field measurements at one particular point. A directional pick-up such as provided by my invention will avoid such errors by completely ignoring the reflected wave.

Various modifications of the principles of uni-directional propagation of energy in coupled wave guides will be evident to those skilled in the art. I therefore prefer not to be bound by the specific disclosures hereinabove set forth, but only by the appended claims.

I claim:

1. In an ultra high frequency system, a first wave guide, a second wave guide having its axis

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at right angles to said first wave guide, and a pair of coupling slots, perpendicular to and bisecting each other in each of said wave guides, the slots in one guide being juxtaposed on the slots of the other.

2. In an ultra high frequency system a first rectangular wave guide, a second rectangular wave guide having its axis at right angles to said first wave guide, and a pair of coupling slots perpendicular to and bisecting each other in the large dimension face of each of said wave guides, the slots in one guide being juxtaposed on the slots of the other.

3. In an ultra high frequency system, a first rectangular wave guide, a second rectangular wave guide having its axis at right angles to said first wave guide, said guides being in contact along the large dimension sides, and a pair of coupling slots perpendicular to and bisecting each other in the large dimension face of each of said wave guides, the slots in one guide being juxtaposed on the slots of the other, the intersection of said slots being along the diagonal formed by the square formed by the engaging surface of said wave guides.

4. In an ultra high frequency system, a first rectangular wave guide, a second rectangular wave guide having its axis at right angles to said first wave guide, and a pair of coupling slots perpendicular to and bisecting each other in the large dimension face of each of said wave guides, the slots in one guide being juxtaposed on the slots of the other, the intersection of said slots being at the point where the transverse and axial currents of said first wave guide are equal.

5. In an ultra high frequency system, a first rectangular wave guide, a second rectangular wave guide having its axis at right angles to said first wave guide, and a pair of coupling slots perpendicular to and bisecting each other in the large dimension face of each of said wave guides, the slots in one guide being juxtaposed on the slots of the other, the intersection of said slots being at the point where the transverse and axial currents of said first wave guide are equal and ninety degrees out of phase.

6. In an ultra high frequency system, a first

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coaxial cable, a second coaxial cable having its axis at right angles to said first coaxial cable, and a pair of coupling slots perpendicular to and bisecting each other in each of said coaxial cables, the slots in one cable being juxtaposed on the slots of the other, the slots being positioned at points where the transverse and longitudinal currents in said first coaxial cable are equal.

7. In an ultra high frequency system, a first coaxial cable, a second coaxial cable having its axis at right angles to said first coaxial cable, and a pair of coupling slots perpendicular to and bisecting each other in each of said coaxial cables, the slots in one cable being juxtaposed on the slots of the other, a stub connection to said first coaxial cable, said slots being at the point of contact of said stub to said first coaxial cable.

8. In a high frequency measuring device, two sections of wave guides at right angles to each other and having engaging surfaces, and a pair of bisecting slots cut in the contacting surfaces at right angles to each other for providing a coupling between said wave guides.

9. In a high frequency measuring device, two sections of coaxial cables at right angles to each other and having engaging surfaces and a pair of bisecting slots cut in the contacting surfaces at right angles to each other for providing a coupling between said coaxial cables.

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