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FREQUENCY SELECTIVE SYSTEM

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FIG. 1.

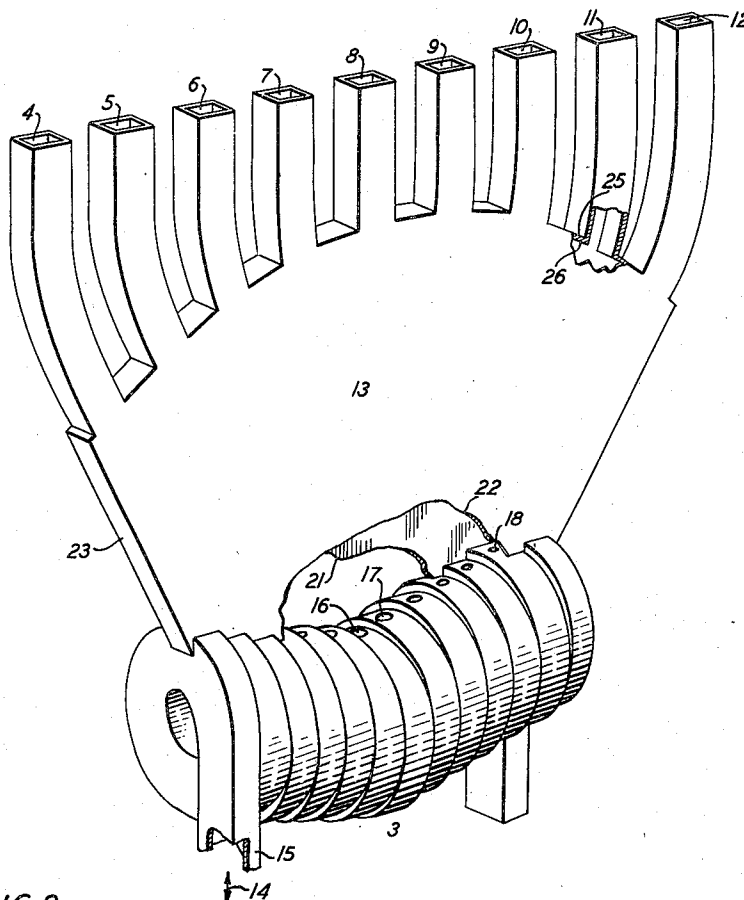
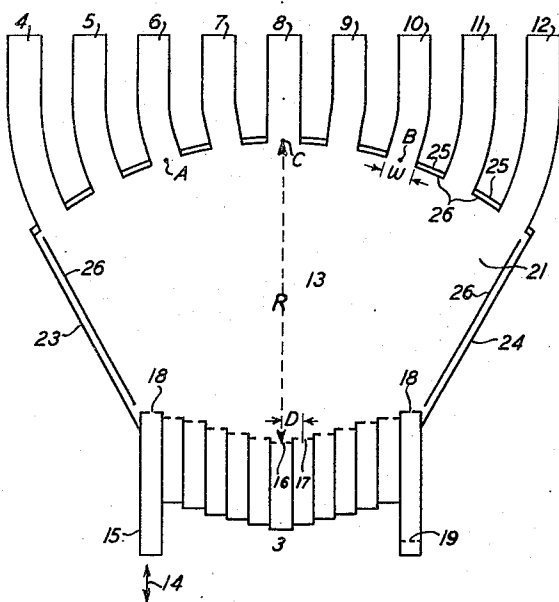


FIG. 2.



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FREQUENCY SELECTIVE SYSTEM

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This invention relates to wave transmission and more particularly to a frequency selective system for separating radiant energy into individual channels on a frequency basis or for combining a number of different bands of frequencies.

The principal object of the invention is to direct multifrequency electromagnetic waves into separate channels according to frequency or to combine a number of separate bands into a single channel.

Another object is to increase the number of channels into which multifrequency electromagnetic waves may be separated on the basis of frequency or from which they may be combined.

A further object is to decrease the size and the cost of a multichannel system for separating or combining guided electromagnetic waves of different frequencies.

Another object is to increase the directivity, as a function of frequency, in a directional microwave radiator.

In wave transmission systems employing coaxial lines or wave guides, it is often required to separate multifrequency electromagnetic waves into individual channels according to frequency or to combine a number of bands into a single channel. A difficulty encountered in such a system, when a parallel arrangement of channel filters is used, is that all of the other filters must have a high impedance over the band of the one under consideration. This difficulty may be overcome in a two- or three-channel system, if the bands are far enough apart, by employing coaxial or wave guide filters with properly designed reactance-annulling stubs. However, this solution is unsatisfactory for a large number of channels with bands close together.

The frequency selective system in accordance with the present invention overcomes these limitations by employing a directional radiator which is the electromechanical equivalent of an optical prism. The system may be designed to separate or combine successfully a dozen or more closely spaced bands of frequencies.

In its preferred form the directional radiator comprises a section of transmission line having an enclosing outer sheath, such as a wave guide or a coaxial line, terminated at one end in its characteristic impedance. The sheath is provided with a number of radiating holes spaced apart an integral number of wavelengths at some frequency f_m and the section of line is coiled into a tight helix so that the holes are adjacent to each other. At the frequency f_m the radiation

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from all of the holes is in phase and there is produced a beam of radiant energy which is normal to the axis of the helix at the central hole. As the frequency is changed from f_m the direction of the beam shifts so that it makes an increasing angle with the normal. For frequencies above f_m the beam shifts to one side and for frequencies below f_m it shifts to the other side of the normal. The radiator may be made more directive by increasing the number of holes and by progressively decreasing their areas from the central to the end holes.

If the axis of the helix is a straight line the directional radiator is focussed on infinity. Such a radiator is useful, for example, in scanning devices of the type employed in object locating and similar systems. Compared with a radiator using an uncoiled line it has the considerable advantage that its directivity may be increased to any desired extent simply by increasing the integral number of wavelengths between the radiating holes, thereby increasing the angular swing of the beam for a given change in frequency.

To provide a frequency selective system, radiant energy pick-up or feed devices are located at the points where the different bands are focussed. Therefore, in order to make the physical size of the filter practicable, the directional radiator is modified so that the bands will have finite focal points. This is accomplished by transversely displacing the coils of the helix so that the radiating holes lie on the arc of a circle. Then waves of the frequency f_m will focus at the center of this circle and frequencies above or below f_m will come to focus at other points lying on an arc which passes through the center. The pick-up or feed devices for the different channels may, for example, be open-ended transmission lines of the type used in the radiator. The width of the open end of the line determines the width of the band of frequencies for each channel.

To prevent undesired radiation and improve the operation of the system the radiant energy is preferably confined between two parallel plates which extend between the radiator and the ends of the pick-up or feed lines. The spaces between the ends of the lines and those between the sides of the parallel plates are preferably closed by a material which, in order to prevent undesired reflections, provides an impedance match for the enclosed propagation medium.

The nature of the invention will be more fully understood from the following detailed description and by reference to the accompanying draw-

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ing, in which like reference characters refer to similar or corresponding parts and in which:

Fig. 1 is a perspective view of a multichannel frequency selective system in accordance with the invention; and

Fig. 2 is a schematic sectional view of the system.

In the embodiment shown, the system comprises a directional radiator 3, nine transmission lines 4 to 12, and an interconnecting chamber 13. Multifrequency electromagnetic waves are introduced or withdrawn at one end of the radiator 3, as indicated by the double-pointed arrow 14, and the separate frequency bands are taken off or fed in through the channels 4 to 12. The system may be used either to separate or to combine a number of bands of frequencies.

The directional radiator 3 comprises a section of rectangular wave guide 15 having a series of thirteen circular holes such as 16, 17, 18 in one of its side walls. These holes have a uniform spacing between centers, as measured along the axis of the guide 15, equal to an integral number, greater than unity, of wavelengths within the guide at some frequency f_m which is preferably the geometric mean of the multifrequency waves. The section 15 is coiled into a helix in such a way that the centers of all of the holes 16, 17, 18 fall in a plane through the axis of the helix. The coils of the helix are packed tightly together to reduce the distance D between the centers of adjacent holes, such as 16 and 17. Also, in order to reduce this distance the holes are preferably made in one of the narrower sides of the guide 15. The distance D preferably does not exceed a wavelength in the surrounding medium, so that only a single primary beam will be radiated. The guide 15 is terminated in an impedance 19, indicated in Fig. 2, which matches its characteristic impedance over the operating range and absorbs substantially all of the energy that reaches it. This impedance may, for example, be provided by a resistive film placed across the guide 15. The amount of energy radiated by each hole is small compared to that within the guide 15 at that point, and the total amount radiated from all the holes is preferably not more than that absorbed in the end termination 19. The selectivity of the system may be increased by increasing the number of radiating holes and by making their cross-sectional areas progressively smaller from the central hole 16 to the end holes 18.

If electromagnetic waves of the frequency f_m are fed into the left end of the radiator 3 the radiation from all of the holes will be in phase and the resulting beam will be in a direction normal to the axis of the helix at the central hole 16. For higher frequencies the beam will swing to the right and for lower frequencies it will swing to the left. If the holes lie in a straight line these beams will come to a focus only at an infinite distance. Such a radiator is useful in scanning devices and has the advantage that the change in the direction of the beam resulting from a given change in frequency may be increased to any desired extent by increasing the integral number of wavelengths between adjacent holes, as measured along the axis of the guide 15. In a practical case this number may, for example, be of the order of ten or more.

When the radiator 3 is to be used in a filtering system, it is desirable that the beam have a finite focal point. As shown in Figs. 1 and 2 this may be done by transversely displacing adjacent coils

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of the helix so that the centers of the holes all fall on the arc of a circle. As shown in Fig. 2 this circle is centered at the point C and has a radius R. Therefore, at the frequency f_m the radiated energy from all of the holes will be in phase and since all of the holes are equidistant from the center C the energy will be focused at this point. For any other point in space the waves from the different holes will be out of phase and cancellation will occur. For other frequencies, however, there will be a progressive phase shift from hole to hole and waves of these frequencies will be focused at other points. Thus, waves of a certain frequency lower than f_m will be focussed at point A to the left of C and those of a certain frequency higher than f_m will be focussed at a point B to the right of C. All of these points A, B and C fall on a smooth arc. Each of the focal points, such as B, may be determined by setting the phase shift in the medium plus the phase shift in the guide 15 equal for the waves radiated from the two end holes 18 and the central hole 16.

As shown, the pick-up devices are the open-ended rectangular wave guides 4 to 12 directed toward the radiator 3. The end of each guide, such as 10, is centered at the focal point, such as B, for the mid-band frequency of the band carried by that channel. The width w of the open end determines the width of the band for the channel.

The propagation medium between the radiator 3 and the channels 4 to 12 is preferably enclosed in a chamber 13 to prevent undesired radiation. The chamber 13 comprises two fan-shaped parallel plates 21 and 22 extending from the radiator 3 to the ends of the guides 4 to 12. Portions of the plates 21 and 22 are broken away in Fig. 1 to expose the radiating holes 16, 17, 18. The sides of the plates 21 and 22 are connected by the plates 23 and 24 and the spaces between the ends of the guides are closed by the plates 25. In order to prevent undesired reflections of the radiant energy within the connecting chamber 13 the inner surfaces of the side plates 23, 24 and 25 are preferably coated with a material 26 which will match the propagation medium in impedance. The material 26 may, for example, be a thin film of platinum. If the medium is air, which has an impedance of about 377 ohms per square centimeter, the platinum film is made approximately 10^{-5} centimeters thick.

It is to be understood that the frequency selective system described may be used to separate a number of bands of frequencies by feeding the multifrequency electromagnetic waves into the radiator 3 and taking off the segregated bands through the channels 4 to 12 or it may be used to combine a number of different bands introduced through the channels 4 to 12 and taken off at the end of the guide 15.

What is claimed is:

1. A frequency selective system for multifrequency electromagnetic waves comprising a guide for said waves and a device for withdrawing or introducing waves of a selected frequency, said guide having a plurality of apertures in a wall thereof, said apertures having a uniform spacing equal to an integral number, greater than unity, of wavelengths in said guide at an operating frequency, said guide being formed into a helix with adjacent coils transversely displaced so that said apertures are adjacently arrayed in an arc whereby waves of different frequencies when fed into the end of said guide are focussed at different

focal points, and said device being located at one of said focal points.

2. A frequency selective system in accordance with claim 1 which includes a device for withdrawing or introducing waves of another selected frequency located at another of said focal points.

3. A frequency selective system in accordance with claim 1 which includes a chamber enclosing the propagation medium between said apertures and said device.

4. A frequency selective system in accordance with claim 3 in which said chamber comprises a pair of parallel plates extending from said helix to said device.

5. A frequency selective system in accordance with claim 4 in which said chamber includes side walls connecting the sides of said plates and said side walls are lined with a material which provides an impedance match for the enclosed propagation medium.

6. A frequency selective system for multifrequency electromagnetic waves comprising a directional radiator at one end of which said waves are introduced or withdrawn, a plurality of wave guides with open ends directed toward said radiator, and a chamber enclosing the propagation medium between said radiator and said guides, said radiator comprising a section of guide having a series of radiating holes in a wall thereof, said holes having a uniform spacing equal to an integral number, greater than unity, of wavelengths in said apertured guide at an operating frequency, said apertured guide being terminated at one end in its characteristic impedance over the operating range and being coiled into a tight helix with adjacent coils transversely displaced so that said holes are arrayed in an arc of a circle whereby waves of different frequencies when fed into said radiator are focussed at different focal points, said chamber comprising a pair of parallel plates extending from said radiator to said open-ended guides, and the centers of the open ends of said guides being located, respectively, at different ones of said focal points.

7. A directive device for radiating or picking up radiant energy of different frequencies at correspondingly different angles comprising a section of guide at one end of which said energy is introduced or withdrawn, said guide being terminated at its other end in an impedance which absorbs substantially all of the energy that reaches it, having a series of small holes in a wall thereof with uniform spacing equal to an integral number, greater than unity, of wavelengths in said guide at an operating frequency f , and being coiled into a tight helix so that the centers of said holes fall in a plane through the axis of said helix.

8. A directive device in accordance with claim 7 in which said frequency f is approximately the geometric mean of the range of operating frequencies.

9. A directive device in accordance with claim 7 in which the cross-sectional areas of said holes progressively decrease in size from the center of said series to each end hole.

10. A directional device in accordance with claim 7 in which said integral number is at least ten.

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