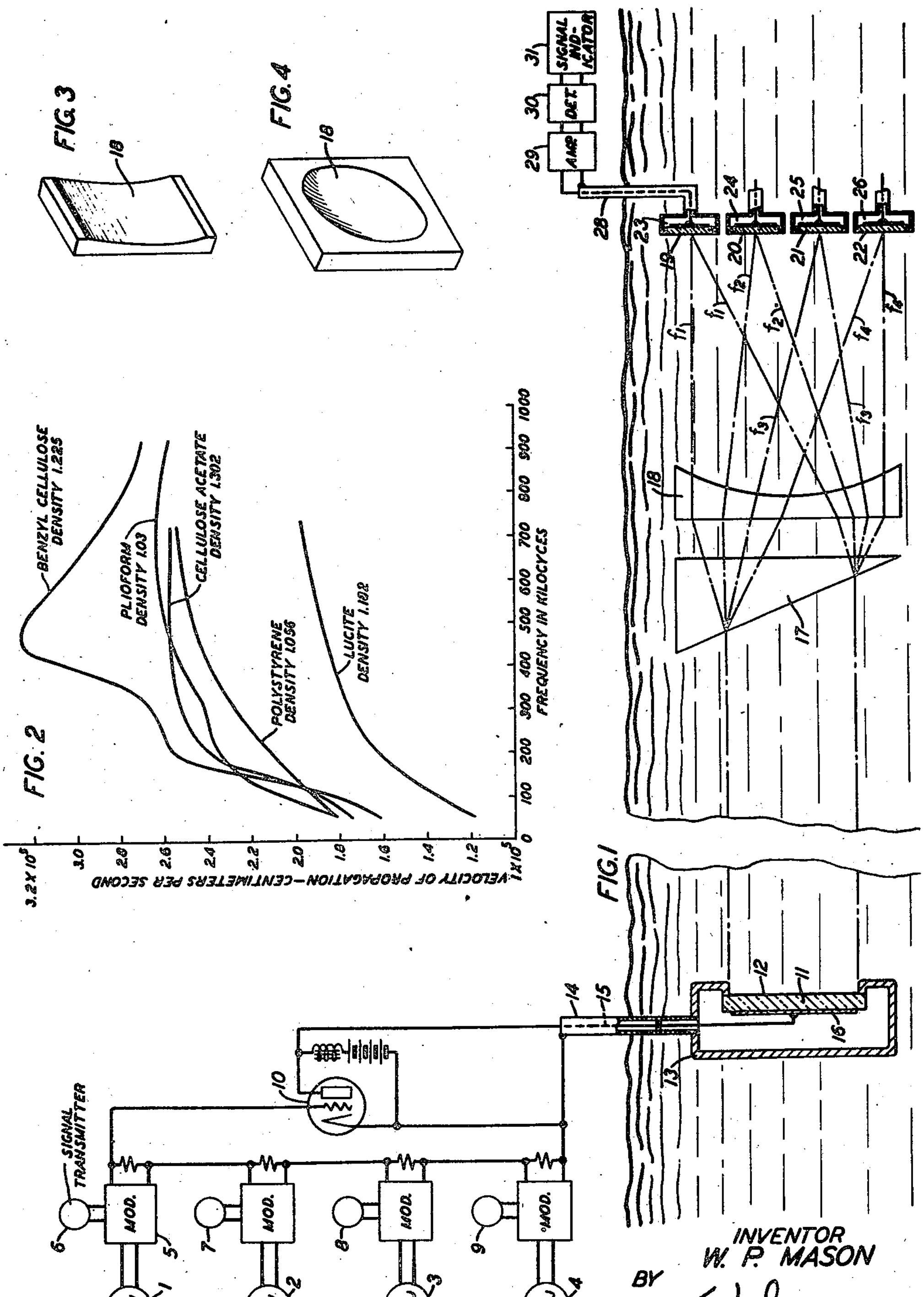
July 8, 1947. W. P. MASON 2,423,459

FREQUENCY SELECTIVE APPARATUS

Filed Sept. 15, 1942



INVENTOR
W. P. MASON

BY E. V. Griggs

ATTORNEY

Patented July 8, 1947 2,423,459

UNITED STATES PATENT OFFICE

2,423,459

FREQUENCY SELECTIVE APPARATUS

Warren P. Mason, West Orange, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application September 15, 1942, Serial No. 458,429

12 Claims. (Cl. 177—386)

1

This invention relates to carrier wave transmission systems and more particularly to frequency selective apparatus for such systems.

A principal feature of the invention is the separation of different frequency compressional wave bands by virtue of the different propagational velocities which the waves experience in traversing prisms and lenses of certain materials.

An object of the invention is to provide simple and effective wave filters which are not dependent upon electrical reactance elements or upon mechanical resonators.

Another object of the invention is to provide filters effective at higher frequency ranges than those for which filters are now available.

In accordance with the invention sound or compressional waves of different frequency bands, each individual band comprising one or more communication channels, are transmitted as a common sound or compressional wave beam. At the receiving terminal the beam is directed upon a body in which the propagation velocity for the waves varies with the frequency of the waves. The body may be immersed in a medium which presents substantially constant propagational velocity characteristics for all of the different frequency waves under consideration. Preferably, the wave propagational velocity in the body and in the medium is substantially equal at an intermediate frequency in the range of frequencies which is utilized. At higher frequencies of that range the wave velocity in the body may exceed that in the medium while at lower frequencies it may be less. Accordingly, the various bands in traversing the body and emerging from it into the medium experience refractions which are different and the bands are, accordingly, dispersed as are the different colors of light rays in passing through a dispersion prism. The separation of the different frequency bands may be accentuated by a lens which focusses them into a limited space at an angle determined by the frequency.

The invention will be more readily understood from a consideration of the following detailed description taken in connection with the accompanying drawings in which Fig. 1 illustrates schematically a four-channel multiplex communication system utilizing supersonic carrier waves;

Fig. 2 shows the graphs of several plastic materials relating propagation velocity of compressional waves to frequency of the waves; and

Figs. 3 and 4 are perspectives of two different forms which the supersonic lens 18 of Fig. 1 may take.

2

Referring to Fig. 1, the four different carrier frequency oscillators 1, 2, 3, 4 are each connected to the input terminals of an individual modulator 5 to which is also connected a respective signal source 6, 7, 8, 9 as, for example, a teletypewriter or a telephone line. Modulated carrier frequency electric waves of the four different frequency bands resulting are superposed upon the input circuit of a thermionic amplifier 10 to the output of which a submarine piezoelectric compressional wave source 11 is connected. The device 11 is preferably highly directive in character and emits a beam of supersonic energy comprising the four different frequency modulated wave bands.

The compressional source 11 may preferably be a piezoelectric plate, the outer face 12 of which may be exposed to the water or may be provided with a conductive coating surface or other type of electrode serving as a diaphragm so that vibrations of the piezoelectric element may be imparted to the water. The element 11 may be otherwise enclosed within a water-tight casing 13 shown partly in section and preferably of metallic character. The output circuit of thermionic amplifier 10 may be connected through a coaxial conductor 14, the outer member of which is directly in contact with the water and leads to the metallic casing 13 and the front electrode 12 of piezoelectric sound source 11. The inner conductor 15 of the coaxial connection is electrically connected to the rear electrode 16 of the sound emitter 11. Accordingly, the device 11 will, because of its larger area flat surface 12, transmit to the water a corresponding broad beam of highly directive sound waves comprising the entire range of frequencies of the currents impressed upon it by the amplifier 10.

At the receiving point the beam of compressional waves impinges upon a prism 17. Any material which exhibits a different propagational velocity for compressional waves than does the water through which the beam arrives may be used as a refracting prism. For use in the system of this invention, an additional property is very desirable, namely, that the propagational velocity for compressional waves in the material varies with the frequency of the waves, since such a material will refract the different frequency compressional waves differently in a manner similar to that by which a dispersion prism differently refracts different colors of light.

It occurred to applicant following a study of anomalous behavior of certain dielectrics that such substances might also exhibit an anomalous propagational velocity for compressional waves. Applicant's researches have demonstrated the correctness of this surmise. The reason for the anomalous wave propagation behavior of these materials is not known but it appears possible that it may be associated with resonant domains in the material which may be a function of long chain molecules that experience a rotary displacement when a body of the medium as a whole is subjected to longitudinal stress. Below the resonance frequency of the domain the domain follows the longitudinal field while above the resonance frequency the field is too fast for the domain to follow. If such plastics as "lucite" (methyl methacrylate) cellulose acetate, and other similar materials are subjected to alternating electric fields there is found to be an absorption of the electric energy or a dielectric loss at "resonance frequencies" which is peculiar to these materials. Applicant has discovered that similar absorptions of acoustic or compressional wave energy occurs in these materials at about the same frequency. He has also discovered that certain other materials such as "plioform" and polystyrene constitute a second class or species which appear to exhibit no anomalous electrical absorption but do, however, exhibit definite acoustic absorption at what appears to be a resonance frequency of an interior domain.

Plastics are found, in general, to have a somewhat higher velocity of propagation for sound waves than does water. Turning to Fig. 2 which shows the results of measurements made on five materials, namely, "lucite," polystyrene, cellulose acetate, "plioform" and benzyl cellulose, it will be noted that for each of these materials the velocity of propagation varies markedly in the range of 100 to 900 kilocycles. In obtaining these measurements it was necessary to eliminate another effect which also causes an increase of velocity with increase of frequency. This effect is the difference in propagation in a long bar and in a thin plate. The first velocity, that is, that of the long bar, depends on the Young's modulus of the material, whereas the second velocity, that in the thin plate, depends on the bulk modulus and the velocity corresponding to the latter is higher. In the measurements of which the results are given in Fig. 2 the width and thickness of the plate was made larger than a wavelength for all measurements and, consequently, the velocity measured corresponds to plate velocity due to the bulk modulus. Additional details of methods and circuits suitable for such measurements may be found at pages 244 to 247 of the book by W. P. Mason entitled "Electromechanical Transducers and Wave Filters," published by D. Van Nostrand Company, Incorporated, New York 1942.

The prism **17** of Fig. 1 may, accordingly, comprise an acoustic refracting element or prism of "lucite" (methyl methacrylate) or a similar material having different propagational velocity characteristics for different frequency sounds. Assume, for example, that the four channels of the multiplex system of Fig. 1 lie in the range of 100 to 165 kilocycles, the individual bands extending respectively from 100 to 105 kilocycles, 120 to 125 kilocycles, 140 to 145 kilocycles, and 160 to 165 kilocycles. At 100 kilocycles the velocity of sound in "lucite" is lower than in water and the mid-frequency elements of beam f_1, f_1 of the 100 to 105 kilocycle beam will therefore be bent as indicated in passing through the prism. At 120

kilocycles the velocity of sound in "lucite" is about equal to that in water and so the mid-frequency components of the corresponding band f_2, f_2 will pass substantially straight through the prism. At higher than 120 kilocycles the velocity of sound in "lucite" increases at least as far as 725 kilocycles and exceeds that in water so that the beams f_3, f_3 and f_4, f_4 of 140 to 145 kilocycles and 160 to 165 kilocycles respectively, will be refracted in a direction opposite to that in which the beam f_1, f_1 is refracted.

Although the bands after refraction by the prism are directed in different directions from each other they will, if of large cross-sectional area, overlap for a relatively long distance after leaving the prism. Moreover, due to the diverging effect which occurs in the beam this overlap will be still further augmented thus making it difficult to separate the beams with apparatus of reasonable dimensions. In order to overcome this difficulty a supersonic lens **18** may be introduced beyond the prism **17** having such characteristics as to focus the various beams. The lens **18** may be of cylindrical form as shown in Fig. 3, or spherical as shown in Fig. 4, in which instance the lenticular surface should have a superficial area somewhat greater than that of the prism in order to encompass all of the beams which have passed through the prism. If the lens be of cylindrical form as in Fig. 3, it will focus the beam f_1, f_1 along a line **19** perpendicular to the plane of the paper. If the lens be of the spherical form of Fig. 4, the beam will be focussed at a point **19**. Similarly, the other three beams may be focussed respectively at **20**, **21** and **22**. It is, therefore, necessary only to position individual sound receivers **23**, **24**, **25** and **26** at the respective foci of the beams in order to pick up these beams. In the case of the cylindrical prism **18**, the receiver **23** may be elongated so as to pick up the effect along the line **19**. If, however, a spherical lens such as is shown in Fig. 4 be used the receiving element of receiver **23** may have a relatively small superficial area. While any type of sound wave receiving device may be utilized a very satisfactory form may correspond in its general structure to the sound emitter **11**. Such a receiver may comprise a piezoelectric element constructed of Rochelle salt which presents a high piezoelectric constant and is, therefore, very sensitive to sound energy. As indicated, the receiver **23** is connected by a coaxial conductor **28** to an amplifier **29** to the output of which a detector **30** and a signal indicator **31** are connected in tandem. The signal indicator will preferably be designed to cooperate with the signal transmitter **6**. If, therefore, the transmitter **6** be a telephone microphone the signal indicator **31** may appropriately be a telephone receiver. If the signal transmitter **6** be a teletypewriter transmitter, the signal indicator **31** may, correspondingly, be a teletypewriter receiver. It will be understood that each of the remaining sound receivers **24**, **25** and **26** will be associated with corresponding apparatus individual to that receiver to enable the individual messages to be received, selected and interpreted each without interference from the other.

The lens **18** shown in more detail in Figs. 3 and 4 may consist of any suitable material having the property of focussing sound waves when immersed in water or the medium in which it is to be used. In order to have this property it is merely necessary that it present a higher propagation velocity for sound waves than does the medium in which it is immersed. Accordingly, a body of almost any solid material not having disturbing resonance frequencies of its own may serve, although if reflections from the surface are to be avoided, the impedance of the lens should not differ greatly from that of the liquid. An example of a material which is suitable for this purpose is "tenite II" (cellulose acetate butyrate) which has a velocity slightly higher than that of water but constant over the frequency range of interest for the filter described here. Other materials which might be used are "catalin," (phenol formaldehyde-cast) and various other plastics.

Although the invention has been illustrated as embodied in a supersonic wave transmission system it is of general application and is not limited to such systems. The compressional wave filter may obviously be employed at a repeater or a terminal of a radio system or one involving conducted or guided waves wherever it may be desirable to separate or filter one or more individual wave frequencies or wave bands from others of different frequency. In each such instance the electric wave to sound wave transducer 11 and the prism 17, lens 18 and the compressional wave responsive devices 19 to 22 inclusive, may be employed as a unit to constitute a wave filter.

The piezoelectric sound transmitter 11 and the piezoelectric compressional wave receiving devices 23, 24, 25 and 26 may each consist of Rochelle salt or of quartz. They will be somewhat more efficient if tuned and they may be so designed as to operate over a relatively wide band. This additional selectivity will augment that obtained by the refraction and focussing features of the invention.

What is claimed is:

1. In a frequency selective system for compressional waves, a device for directing compressional waves having a substantially plane wave front comprising a solid homogeneous mass of material having a propagation velocity for compressional waves which varies with frequency whereby the refraction to which the waves are subjected by the device varies with frequency.

2. A frequency selective device for compressional waves comprising in combination a solid homogeneous prism of material having a propagation velocity for compressional waves which varies markedly in the frequency range of the compressional waves, means directing a beam of compressional waves of different frequencies against said prism and means positioned to receive from said prism at least one component frequency of said compressional wave beam refracted from said prism.

3. A solid homogeneous prism of selected material having a plane face in contact with a medium which has a vibrational propagation velocity for compressional waves equal to that of the material for vibrations of a given frequency and which has a vibrational propagation velocity for compressional waves higher than that of the material for vibrations of substantially lower than the given frequency, and means responsive to compressional vibrations transmitted through said prism and said medium for actuating a signal device.

4. A solid homogeneous prism of selected material having a plane face in contact with a medium which has a vibrational propagation velocity for compressional waves equal to that of the material for vibrations of a given frequency and which has a vibrational propagation velocity for compressional waves lower than that of the material for vibrations of substantially higher than the given frequency, and means for subjecting said prism to a beam of compressional waves of the order of magnitude of 100 kilocycles frequency.

5. In a system for signaling through a body of water by means of compressional waves of the order of 100 kilocycles frequency, an immersed prism of solid homogeneous material having compressional wave propagation velocity characteristics which vary with frequency whereby the prism serves to differently refract different frequency compressional waves.

6. A filter comprising a source of a beam of sound waves of different frequencies, a solid homogeneous prism in the path of the beam comprising a material having a sound wave propagation velocity characteristic which varies with frequency whereby sound waves of the beam are refracted to an extent depending upon their respective frequencies, a focussing lens intercepting the refracted sound waves to focus them at separate points in accordance with the directions with which they emerged from the prism and a plurality of sound wave responsive devices positioned respectively at said points.

7. A filter comprising a source of a beam of compressional waves of different frequencies, a solid homogeneous prism in the path of the beam whereby compressional waves of the beam are refracted, a focussing lens intercepting the refracted compressional waves to focus them at separate points whereby the compressional waves are focussed at points which are determined by their respective frequencies.

8. A filter system comprising a source of plane sound waves of different frequencies, a refractor for sound upon which a beam of sound waves is projected by the source, the refractor comprising a homogeneous continuous mass of solid material having a refraction characteristic which varies with frequency whereby upon incidence of a sound wave beam comprising a substantially continuous frequency range of components each having a multiplicity of parallel rays the refractor transmits each component so that it emerges with a direction characteristic of its respective frequency and free from interference between its rays so as to present a component beam which is continuously distributed over the emission area of the refractor, and a plurality of sound wave responsive elements in the path of the refracted waves whereby the band of sound wave frequencies selected by each element is determined by its superficial dimension in the direction of refraction.

9. A transmission device comprising a solid mass of homogeneous material, a source of a beam of different frequency compressional waves located to direct the beam upon said mass, said mass having a thickness which varies in the direction of the beam, the propagation velocity of said mass for said waves varying with frequency of the waves.

10. In combination, a source of a beam of multifrequency compressional waves, a solid prism composed of homogeneous material upon which the multifrequency beam of compressional waves is projected by said source and for which the compressional wave propagation velocity varies with frequency, and compressional wave indicating means responsive to energy of at least one of the frequencies of said beam and so positioned as to intercept compressional wave energy of the frequency band to which it is responsive after refraction by said prism.

11. The method of separating a beam of compressional waves into its component frequencies which comprises directing said beam upon a continuous mass of homogeneous material for which the compressional wave propagation velocity varies according to wave frequency.

12. A filter system comprising in combination a source of a beam of compressional waves of different frequencies, a refractor element for compressional waves composed of polystyrene upon which said beam is projected by the source, and a plurality of compressional wave responsive elements in the path of the refracted waves.

WARREN P. MASON.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,895,442	Bowker	Jan. 31, 193
1,455,825	Wood	May 22, 192
2,283,285	Pohlman	May 19, 194
2,100,348	Nicolson	Nov. 30, 193
2,278,940	Murphy	Apr. 7, 194
2,169,304	Tournier	Aug. 15, 1939
2,240,988	Hertel	May 6, 1941
1,682,572	Keuffel	Aug. 28, 1928
2,233,062	Pineo	Feb. 25, 1941
818,534	Gerard	Apr. 24, 1906

FOREIGN PATENTS

Number	Country	Date
279,878	Great Britain	Mar. 8, 1928