Sept. 24, 1963 H. F. OLSON 3,105,113

STEREOPHONIC LOUDSPEAKER SYSTEM

Filed July 15, 1960 2 Sheets-Sheet 1

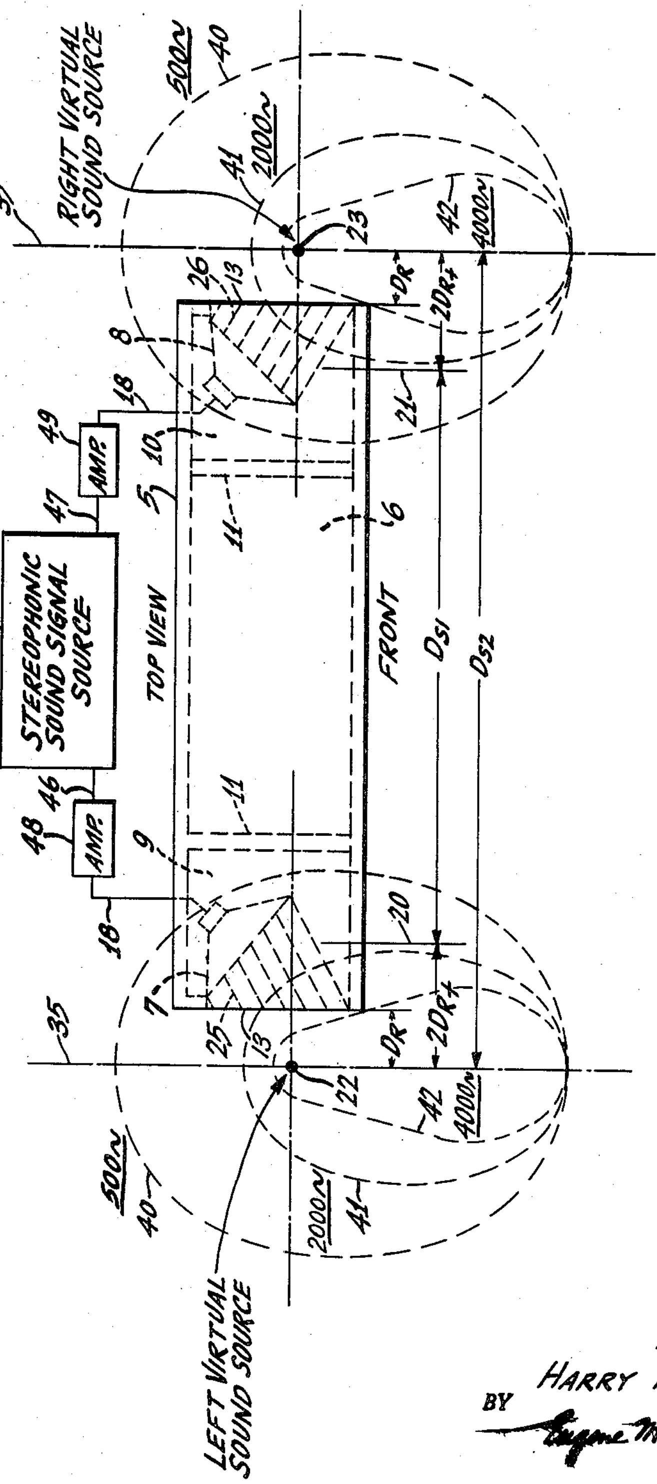

Fig. 1.

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Fig. 3.

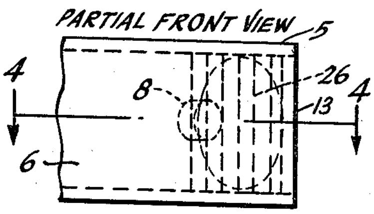
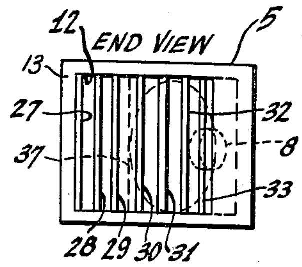


Fig. 2.



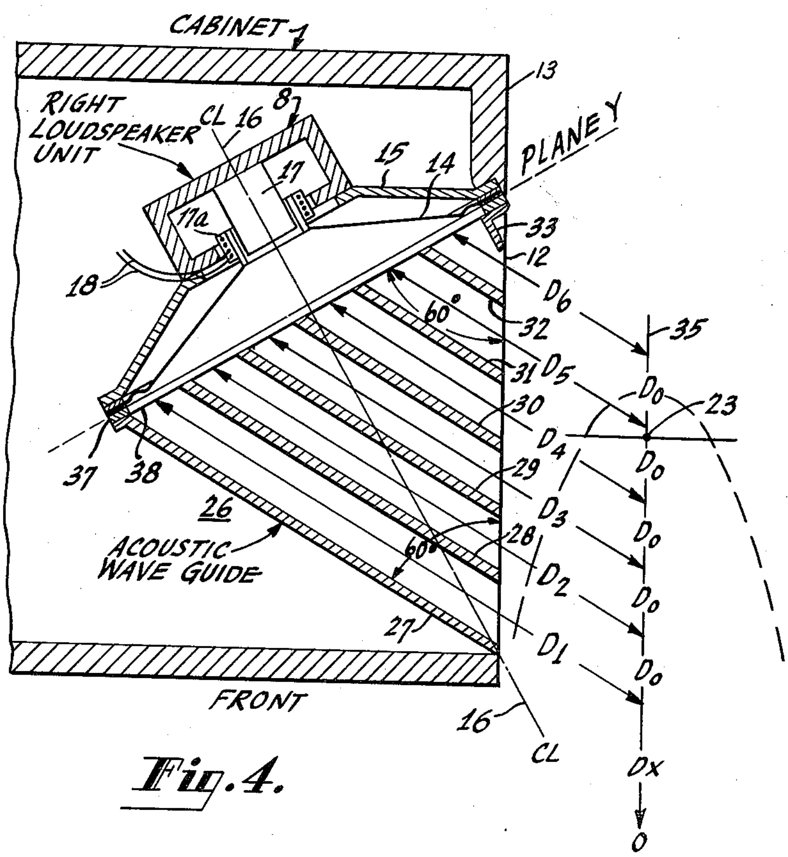


Fig. 4.

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3,105,113
Patented Sept. 24, 1963

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3,105,113
STEREOPHONIC LOUDSPEAKER SYSTEM

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Filed July 15, 1960, Ser. No. 43,040
6 Claims. (Cl. 179—1)

The present invention relates to stereophonic sound-reproducing systems, and more particularly to loudspeaker systems for two-channel stereophonic sound reproduction in radio receivers and the like.

Two-channel stereophonic sound reproducing systems provide for translating two stereophonically-related audio-frequency sound signals, such as may be derived from two spaced microphones at an original sound source or the recordings or radio transmission thereof, through separate signal channels and individual sound-reproducing loudspeaker means for each channel. It is important for sound reproduction in proper auditory perspective, to provide relatively wide spacing between the sound sources as reproduced by the loudspeaker means.

Stereophonic sound reproduction by means of magnetic tape and disc records has become an important medium in the home entertainment field. Compatible systems for the transmission of stereophonic sound in both AM and FM radio broadcasting have been developed, and transmission of stereophonic sound on these two media commercially may be initiated as soon as standards are established. Thus there may be four stereophonic sound systems for commercial use in the home entertainment field to provide effective stereophonic sound reproduction, namely, the disc phonograph, the magnetic-tape reproducer, the AM radio and the FM radio.

The transmission of stereophonic sound by means of AM and FM radio presents the need for table-model stereophonic radio receivers that may be housed in a single cabinet. This requires loudspeakers for two-channel stereophonic sound reproduction, in a single cabinet or cabinet structure of relatively small dimensions. Under these conditions the separation of the loudspeakers or loudspeaker units, and the virtual sound sources created thereby, must likewise be relatively small. As mentioned above, in stereophonic sound reproduction the spacing between the loudspeakers is important in producing a desired degree of auditory perspective or stereophonic effect in a listening area. Therefore, it is desirable to increase the separation between the sound sources with small table-model radio or like cabinet structures for two-channel stereophonic sound reproduction, thereby to overcome the physical limitations imposed by the small cabinet dimensions.

It is, therefore, an object of this invention to provide a table-model loudspeaker system for two-channel stereophonic sound reproduction which gives effective stereophonic sound reproduction in good auditory perspective with a single cabinet of relatively small dimensions.

It is also an object of this invention to provide an acoustical system for table-model and like small radio receivers and like apparatus, in which the separation between the virtual sound forming part thereof and which may be mounted in a relatively-small unitary cabinet structure for the apparatus.

It is a further object of this invention to provide a two-channel table-model stereophonic loudspeaker housed in a single cabinet and including an acoustic system which gives augmented separation for the virtual sound sources without increasing the lateral dimensions of the cabinet, and improved sound response therefrom in a forward direction.

Means have been proposed heretofore for employing spaced loudspeaker means in a single small cabinet structure, as shown, for example, in the patent to Crosley et al., 2,002,390. The Crosley structure causes the sound to be distributed laterally but not directly forwardly. Although such structures increase the effective separation of the vertical sound sources from the two speakers, they do not provide good quality sound reproduction at the customary listening location in front of the cabinet due to a lack of high frequency response in the frontal direction.

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Accordingly, it is a further object of this invention to provide an improved and unitized stereophonic loudspeaker system embodying a table-model radio receiver or like cabinet structure of relatively small size which will give good quality sound reproduction in good auditory perspective from sound sources that appear to be spaced farther apart than the length of the receiver cabinet.

In accordance with the invention, a loudspeaker system for two-channel stereophonic sound reproduction embodies the feature that the sound sources extend beyond the ends of the cabinet structure, in laterally spaced relation, so that an effectively wider spread between the actual loudspeaker sound sources is obtained. The effectively wider spread is combined with forward sound projection which is accomplished by means of acoustic wave guides within the ends of the cabinet structure. Each of these wave guides includes a series of sound-wave-directing vertical vanes or partitions, in parallel relation, at an angle to the end of the cabinet structure and to the plane of the face of a direct-radiator type loudspeaker unit, which plane is generally vertical and at an acute angle to the end of the cabinet structure. The loudspeaker units preferably may be of the relatively-small conical-diaphragm type having a central voice-coil and a flexibly mounted, or flexible, cone rim or edge carried by the usual frame or spider which also carries the field structure.

This system is thus particularly adapted for applications requiring reproduction of two-channel stereophonic sound from table-mode radio receivers having small cabinets and like housing means. In any case, the loudspeaker units or mechanisms are spaced apart in stereophonic relation in separate left and right end sections of the enclosure or housing means, facing semi-forwardly against the wave guides. The enclosure or housing means is a single cabinet, generally rectangular and elongated when practical, of table-model dimensions. The loudspeaker units mounted in the spaced ends or sides of the cabinet increases the effective distance between the virtual sound sources of the loudspeakers by a distance of substantially twice that of the diameter of the loudspeaker cone, which may, depending on cabinet length be twice that which is possible with the ordinary spaced mounting of the loudspeaker units in the front of the cabinet. The acoustic wave guides direct the sound waves or radiations from the end-mounted loudspeakers in a forward direction, so as to insure sufficient high frequency response in front of the cabinet to provide good quality sound reproduction.

These units are connected for operation stereophonically in response to applied two-channel stereophonic sound signals from the radio receiver, or other suitable source which is included in the enclosure or housing means. The loudspeaker system therefore has two signal input circuits, one connected with the right-hand loudspeaker unit and the other connected with the left-hand loudspeaker unit, and is particularly adapted for use in table-model AM and FM stereophonic radio receivers.

It may, therefore, be considered to be a specific object of this invention, to provide a single-unit stereophonic loudspeaker system which operates to reproduce stereophonic sound from a two-channel stereophonic radio signal source, in a forward or frontal direction and with good auditory perspective, and which may simply and effectively be housed and baffled in a unitary cabinet structure or like enclosure means of limited dimensions required for table-model radio apparatus, whereby it is adapted for use therewith in developing stereophonic sound reproduction through AM and FM radio broadcasting.

The invention, together with further objects and advantages thereof, will further be understood from the following description of certain embodiments when considered in connection with the accompanying drawings, and its scope is pointed out in the appended claims.

In the drawings,

FIGURE 1 is a top view of a stereophonic loudspeaker system embodying the invention, together with diagrammatic representations of sound patterns illustrating a principle of operation thereof;

FIGURES 2 and 3 are end and frontal views, respectively, of the sound system shown in FIGURE 1, FIGURE 3 being broken away and showing only one end portion of the structure of FIGURE 1 to simplify the drawing; and,

FIGURE 4 is a diagrammatic plan view, in cross-section as taken on section line 4—4 of FIGURE 3 and on an enlarged scale, showing further details of construction and certain principles of operation of the system of FIGURE 1.

Referring to the drawings, in which, throughout the various figures, like reference characters are used to refer to like elements, a small cabinet **5** of rectangular box-like construction is shown as of the type adapted for a table model radio receiver and the like. As will be seen from an inspection of the top, end, and front views of FIGURES 1, 2, and 3 respectively, the cabinet is provided with a central interior space or section **6** for housing stereophonic radio and like apparatus which may be provided to drive two stereo-channel loudspeaker units **7** and **8**, located respectively in left and right-hand end chambers **9** and **10** in the cabinet. The end chambers are provided with partitions **11** extending across the interior of the cabinet, as indicated, to separate the loudspeakers from the apparatus where there is any problem of acoustic feedback encountered. Each end or side wall of the cabinet is provided with a relatively large rectangular sound-conducting opening communicating with the adjacent end chamber, as shown more particularly at **12** in FIGURE 2, toward which the respective speaker units are angularly faced as indicated in FIGURE 1. The end or side walls, as in the present example, are generally substantially parallel and vertical, and the cabinet structure is rectangular.

As shown more clearly in FIGURE 4, each loudspeaker unit is mounted at an acute angle to the adjacent end of the cabinet and is of the direct-radiator type having a conical-type diaphragm **14** the front face of which stands in a vertical plane Y which is located, in the present example, at substantially 60° to the plane of the end wall **13** of the cabinet or the opening **12** therein. The axis or center line **16** of the speaker unit forms an acute angle, with respect to the opening **12** and the end of the cabinet. In the present example this is substantially 30° with respect to the end of the cabinet and the loudspeaker unit, therefore, is positioned to direct sound from the conical diaphragm **14** substantially forwardly or frontally of the cabinet in a general direction as indicated by the center line **16**.

The loudspeaker units, as indicated in FIGURE 4, provide flexible rim mounting for the conical diaphragm **14** in a frame or spider **15** which carries the field structure **17**, and the voice coil **17***a* which is connected with the rear end or center of the diaphragm **14**. Suitable signal supply leads **18** are provided for the voice coil. These units represent any conventional direct-radiator conical-diaphragm type loudspeaker units that are adapted for use in small radio cabinets. In the present example these units may be considered to be typical 8 inch direct-radiator loudspeaker mechanisms, in which case the diameter of the face of each speaker diaphragm or cone is substantially 7 inches. In relation to this size speaker, the cabinet size as herein shown, may be considered to be substantially 9 inches high, 10 inches deep and 30 inches wide on the outside. As shown in FIGURE 2, the openings **12** occupy a major portion of each side or end of the cabinet.

A typical unitary table-model stereophonic loudspeaker system of ordinary construction would have the two speaker units **7** and **8** facing directly frontally at the ends of the cabinet substantially on center lines indicated at **20** and **21** in FIGURE 1. Assuming 8 inch diameter speakers and end wall thickness of 1 inch overall, the center lines **20** and **21** would each be about 5 inches from the ends of the cabinet for widest or maximum separation. This would make the distance D_{S1} equal to approximately 20 inches. The effective separation between the two loudspeakers and between the virtual sound sources would thus be limited. In other words, both the physical and subjective location of the sound sources would be the same with this type of construction, and it will be seen that the separation between the sound sources would be small in a table model cabinet of this type.

A unitary two-channel stereophonic loudspeaker system with the direct-radiator loudspeaker mechanisms or units mounted in the ends of the cabinet as shown herein provides an effective separation of the virtual sound sources represented by the distance D_{S2}. From the diagram shown in FIGURE 1 it will be seen that

$$D_{S2}=D_{S1}+4D_R$$

in which D_R is approximately equal to the radius of the loudspeaker unit used. Thus in the present example, the virtual sound source to the left and to the right of the ends of the cabinet is moved outwardly by a distance D_R. The virtual sound sources are indicated schematically in the diagram of FIGURE 1 at the points **22** and **23** respectively. Thus it will be seen that a considerable increase in the spread of the sound sources is obtained by mounting the loudspeaker mechanisms in the ends of the cabinet. Assuming that D_R is approximately 4 inches in the present example, the additional separation of the sound sources is thus 16 inches plus the thickness of the cabinet walls at the ends, which may be considered as additional two inches, so that the 20-inch spacing represented by the distance D_{S1} is substantially doubled for the distance D_{S2}. This represents a considerable improvement in the spacing of the sound sources without extending the width of the cabinet.

The construction shown in the Crosley patent referred to, wherein the speaker units face the ends of the cabinet, does not provide as high a quality of sound reproduction as may be desired due to a lack of high frequency response forwardly or frontally of the cabinet, which is assumed to be the customary listening location with a stereophonic sound reproduced system.

However the stereophonic loudspeaker system of the present invention provides for spreading the virtual sound sources as shown while restoring the high-frequency response in the forward direction. As indicated in FIGURES 1, 2 and 3 and as shown more clearly in FIGURE 4, acoustic wave guides **25** and **26** are provided respectively in the left and right hand compartments to direct the sound waves from the loudspeaker units in a definite forward direction in accordance with the arrangement shown in detail in FIGURE 4.

Considering the construction shown in FIGURE 4, the acoustic wave guide **26**, representative of both wave guides, comprises a plurality of substantially parallel vanes or guides **27–33**, inclusive, standing vertically and extending between the plane Y of the speaker diaphragm and the opening **12** or end wall **15** of the cabinet. A sufficient number of vanes are provided, in this case seven, to define and divide the sound conducting area of the wave guide, between the diaphragm and the end opening **12** of the cabinet, into ducts which are relatively thin and less than one wave length in width or thickness, and of gradually decreasing length from front to rear of the cabinet. In other words the vanes or guides are spaced less than one wave length apart, at the highest useful frequency of transmission. They are in substantially parallel vertical planes extending between the plane of the diaphragm and the end opening in the cabinet and operate to convey sound waves from the speaker unit and direct them forwardly in an area centered along a line graphically represented at 35 passing through the virtual sound source 23. This line may thus be taken as representative of the general direction of the sound frontally. Since it passes through the virtual sound source 23, it is shown at a distance from the end of the cabinet substantially equal to the radius of the loudspeaker unit diaphragm.

The geometry of the wave guide, cabinet and speaker relation at each end of the cabinet, as depicted in FIGURE 4 may now be considered. The outer ends of the vanes or guides 27–33 project into the openings at the ends of the cabinet, such as the opening 12, and at their inner ends terminate at the forward or frontal plane of the speaker diaphragm, such as the plane Y. This is adjacent to a baffle board 37 of rectangular shape extending from top to bottom of the interior of the cabinet, as indicated in FIGURE 2. The baffle board 37 has an opening 38 conforming to the size of the speaker diaphragm for transmitting the overall sound through the wave guide. As was indicated in FIGURE 2, the wave guide vanes extend from top to bottom of the end openings such as 12 to provide complete control of the direction of sound propagation from each end of the cabinet.

Between the vanes or guides there are acoustic sound paths which are designated by the arrowed directional lines D_1–D_6 extending from the plane Y to the center line 35, along which line are designated the distances D_0 indicating the incremental sound path lengths between the different acoustical guide channels. Along the line 35, the final distance to any chosen listening point θ is indicated by the distance D_X. The distance D_X may be any distance frontally of the listening point from the sound output area of the wave guide. The following relation exists with regard to the acoustical path lengths:

$$D_1+D_X=D_2+D_0+D_X=D_3+2D_0+D_X=D_4+3D_0+D_X=D_5+4D_0+D_X=D_6+5D_0+D_X$$

Thus it will be seen that the acoustic path lengths from the plane Y through the wave guide to the point θ are all the same. If the phase of the sound waves over the plane Y is the same, the sound waves from the six paths will arrive at the point θ in the same phase. The sound output of the loudspeaker 8, and likewise of the loudspeaker 7, is therefore directed forwardly, as is desirable for better sound coverage of the listening area frontally of the cabinet.

Assuming that an upper frequency of 5000 cycles may represent a reasonably good high-frequency response from the loudspeaker system for table-model radio receivers and the like, it will be seen that the wave-length of the sound at this frequency will be two and six tenths inches, whereas the spacing between the wave-guide elements or vanes is slightly over 1½ inches in the present example. Therefore the vanes or guide walls preferably are spaced apart less than one wave-length at the assumed highest useful operating frequency for the loudspeaker system.

Also it may be observed that the end of the cabinet or the plane of the opening 12, the plane of the loudspeaker baffle 37 or the plane Y, and the planes of the wave-guide elements 27–33, are all generally vertical when the cabinet setting is in the normal manner, such as setting on a horizontal surface like a table or shelf. Thus the sound from the speaker units is changed in direction by the wave guides and directed outwardly and forwardly from the ends of the cabinet and in horizontal direction. The planes of the wave-guide vanes extend between and intersect the planes of the openings in the cabinet ends and the planes of the loudspeaker diaphragms. The planes of the loudspeaker diaphragms, that is the plane Y in FIGURE 4, are likewise at angles of 60° to the ends of the cabinet as is each of the guide vanes. The area within the wave-guide, in the present example, is therefore an equilateral triangle, the sides of which substantially equal the diameter of the loudspeaker unit with which it is associated.

While the wave-guide vanes are shown as being straight, it should be understood that they may be curved or variously shaped and positioned at different angles with respect to the cabinet and end openings whereby they provide similar geometrical relations for the path lengths of the sound waves as provided in the example shown. In any case the wave-guide vanes are at such angles to the plane Y that the sound waves from the loudspeakers are deflected and directed through the ducts or channels of the wave guides in a frontal and right and left direction as the case may be, at each end of the cabinet to provide stereophonic sound distribution in depth frontally and with good auditory perspective.

The directivity patterns of typical 8 inch direct-radiator loudspeaker mechanisms and acoustic wave guide systems as above described, are shown in FIGURE 1. Only three of the uniform sound amplitude curves are directly shown. These are indicated for 500 cycles at 40, for 2000 cycles at 41, and for 4000 cycles at 42. In some cases the sound output will vary from the patterns shown and in many cases may extend slightly to the right and left, at different angles forwardly toward the front, depending upon the location and background for the cabinet 5. The performance from the standpoint of directivity is superior to that of a system in which the speaker units face fully into the ends of the cabinet, and is substantially the same as that for front-mounted mechanisms as referred to in the description in FIGURE 1. The increase in the effective distance between the virtual sound sources represented by the distance D_{S2} and the points 22 and 23, with respect to the distance D_{S1}, is substantially twice the diameter of the direct-radiator loudspeaker mechanisms in the cabinet shown. This is a significant increase in separation which is of particular importance in small unitary sterophonic loudspeakers.

The loudspeaker system may be operated from any suitable source of stereophonic sound signals indicated by the block unit 45 in FIGURE 1. This may be considered to be a stereophonic FM or AM radio receiver mounted in the cabinet in the center section 6 and having two stereophonic output circuits 46 and 47 for the left and right channels respectively, which are connected through suitable audio-frequency amplifiers 48 and 49, respectively, with the input circuit leads 18 of the loudspeaker units. Like the receiver elements, the amplifiers 48 and 49 may be mounted in the center section of the cabinet. The application of stereophonic sound signals to the speaker system from the signal source 45 provides stereophonic forwardly projected sound patterns in front of the cabinet and in auditory perspective, from the two virtual sound sources 22 and 23. With a relatively small cabinet structure such as that indicated in the present example, the spacing of the virtual sound sources is increased from approximately 20 inches to nearly twice that distance by the loudspeaker system as shown and described.

The unitary loudspeaker system of the present invention is thus embodied in a single cabinet that may be of table-model dimensions. The direct-radiator loudspeaker mechanisms are mounted in the ends of the cabinet, which increases the effective distance between the virtual sound sources of the loudspeakers by a distance of twice the diameter of the loudspeaker, as compared to mounting the loudspeakers in the front of the cabinet. The acoustic wave guides direct the sound radiations from the end-mounted loudspeakers in a forward direction.

Having described the invention, what is claimed is:

1. A stereophonic loudspeaker system for the reproduction of sound in auditory perspective, comprising, in combination, a cabinet having two end walls with a sound-conducting opening in each of said walls and a front wall, a pair of loudspeaker units mounted in said cabinet each angularly facing frontally and outwardly toward an adjacent end wall opening, means providing a sound-directing wave guide acoustically connecting each of said loudspeaker units with the adjacent end wall opening for conducting sound waves therefrom in auditory perspective outwardly and forwardly with respect to the ends of said cabinet, said sound directing wave guide comprising a plurality of vanes of differing lengths extending from a loudspeaker unit to its adjacent end wall, said vanes increasing in length from the back towards the front of said cabinet and means providing a stereophonic sound-signal source connected with said loudspeaker units in two-channel stereophonic operating relation.

2. A stereophonic loudspeaker system for the reproduction of sound in auditory perspective, comprising, in combination, a table-model radio cabinet having two end walls with a relatively large sound-conducting opening in each of said walls, a pair of direct-radiator type loudspeaker units mounted one in each end of said cabinet and angularly facing frontally and outwardly toward the adjacent end-wall opening in said cabinet, a pair of sound-directing wave guides mounted in the end portions of the cabinet and acoustically connecting the face of each of said loudspeaker units with the adjacent end-wall opening of the cabinet, said wave guides each comprising a plurality of substantially vertical vanes in spaced relation to each other, said vanes being spaced less than one wave-length apart at the highest operating frequency for said system and providing sound-conducting paths of substantially equal length from the face of each loudspeaker unit forwardly of the cabinet from each end thereof and a virtual sound source established by the associated loudspeaker unit, and radio receiver means providing a stereophonic sound-signal source connected with said loudspeaker units in two-channel stereophonic operating relation.

3. A stereophonic table-model radio loudspeaker system, comprising, in combination, a radio cabinet of table-model dimensions and rectangular configuration having two substantially parallel and spaced end walls with a sound conducting opening in each of said walls and occupying a major portion thereof, a direct-radiator conical-diaphragm type loudspeaker unit mounted one in each end of said cabinet and angularly facing frontally and outwardly toward the adjacent end wall opening, said units thereby operating to establish virtual sound sources outside the end walls of the cabinet and an effectively wider spread between the actual speaker unit sound sources, sound directing wave-guide means in each end of said cabinet acoustically connecting the face of each of said loudspeaker units with the adjacent end wall opening, said wave-guide means comprising a baffle element having an opening for the face of the loudspeaker unit and a plurality of substantially vertical vanes in parallel spaced relation to each other, said vanes being of different lengths spaced less than one wavelength apart at the highest useful frequency of operation of the system and extending between the baffle element opening and the adjacent end-wall opening to provide sound paths of substantially equal length from each loudspeaker diaphragm forwardly of said virtual sound sources to a predetermined listening point, and radio receiver means providing a stereophonic sound signal source connecting said loudspeaker units in stereophonic operating relation.

4. A stereophonic loudspeaker system for the reproduction of sound in auditory perspective for small radio receivers and the like, comprising in combination, a table-model radio cabinet structure having two end sections providing laterally spaced end walls each with a sound conducting opening therein, a direct-radiator conical-diaphragm loudspeaker unit mounted in each of said end sections and facing the adjacent end wall opening in substantially a vertical plane and at an acute angle thereto, acoustic wave guide means comprising a plurality of substantially parallel vanes extending between the face of each of said loudspeaker units and the adjacent opening in the end wall of the cabinet structure for directing sound therefrom in a forward direction in auditory perspective, and said acoustic wave guide providing a plurality of sound paths of substantially equal length from the face of each speaker unit in said forward direction at each end of the cabinet structure, thereby to provide inphase sound signals forwardly of said cabinet structure and in said auditory perspective in response to applied inphase stereophonically related sound signals at said loudspeaker units.

5. A loudspeaker system comprising in combination, a substantially rectangular cabinet structure having end walls with relatively wide lateral spacing and sound conducting end openings therein, a pair of loudspeaker units mounted in said cabinet structure and positioned for establishing virtual sound sources externally of the cabinet and beyond the ends thereof in laterally spaced relation, whereby an effectively wider spread is provided between said virtual sound sources than between said loudspeaker units, and acoustic wave guide means within the ends of the cabinet structure and between the end openings and each of the speaker units for directing sound waves effectively from said sound sources in a forward direction and along sound paths of substantially uniform length in response to signals applied to said loudspeaker units, each of said wave guide means including a series of sound-wave-directing vertical vanes in spaced relation and at an angle to the adjacent end of the cabinet structure, said wave guide means acoustically connecting the face of each of said loudspeaker units with the adjacent sound conducting opening in the end wall of the cabinet structure in a series of relatively thin ducts the thickness of each of which is less than one wave-length of the highest useful operating frequency of the loudspeaker system.

6. A unitized table-model stereophonic loudspeaker system for small stereophonic radio signal receivers having two-channel output circuits for two stereophonically-related sound signals, comprising in combination, a single table-model radio cabinet structure having two spaced side walls each with an end opening therein for conveying sound waves externally of the cabinet structure, means providing a central interior section for housing stereophonic radio apparatus, a pair of channel loudspeaker units of the direct-radiator type mounted in the ends of the cabinet adjacent to said openings and angularly spaced with respect thereto in substantially vertical planes having acute angles with respect to the planes of the end openings, circuit means connecting said channel loudspeaker units with the respective channel output circuits for applying said signals to said units, a pair of acoustic wave guides each comprising a plurality of substantially vertical vanes spaced less than one wave-length apart at the highest useful operating frequency of said system and extending different distances between and in registration with the diaphragm face of each speaker unit and the corresponding opening in the end wall of the cabinet structure, the angle of the vanes being such that sound waves from the speaker units are changed in direction thereby and directed in sound paths of substantially equal lengths outwardly and forwardly from the ends of the cabinet structure and in a horizontal direction, the sound waves from the loudspeaker units being thereby deflected and directed through the ducts or channels of the wave guides in a frontal and right and left direction at the respective ends of the

cabinet structure to provide stereophonic sound distribution in depth frontally and with auditory perspective in response to signals applied to said loudspeaker units from said output circuits.

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