Ribbon speaker system.

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Description

The present invention relates to acoustic transducer systems and, in particular, to ribbon speaker systems. At present, there are many types of acoustical transducer or loudspeaker arrangements designed to accurately reproduce sounds in high-fidelity sound systems.

Known from US—A—3,164,686 in an electrodynamic transducer comprising a generally planar diaphragm of very low rigidity which has an electric circuit covering most or all of its area. The circuit is disposed in a magnetic field which is edgewise to the diaphragm and which is locally oriented so as to provide aiding forces over the entire diaphragm as a current is passed through said circuit.

Also known from US—A—3,674,947 is an electromagnetic transducer utilizing one or more vibratable diaphragms, each carrying one or more conductors which may be stacked upon each other on the diaphragm, and a flexible sheet magnet confronting the diaphragm and spaced therefrom and being magnetized in a direction through its thinnest dimension in elongate zones following the conductors on the diaphragm.

The most familiar type of transducer is the well-known cone speaker which produces sound energy by vibrating a cone-shaped transducer element by means of an electromagnetic voice-coil arrangement. Various modifications of this arrangement have been developed including acoustic suspension speakers, motional feedback speakers and other arrangements to reduce distortion and improve fidelity of the reproduced sound.

One of the major disadvantages with cone speakers is that, due to their physical construction, they must be driven over a narrow ring-shaped area. This type of drive induces unwanted structural vibrations in the cone and causes distortion. In addition, most cone speakers have limited dispersion. That is, the sound quality perceived by a listener located in a room with such a speaker changes when the listener moves about the room. In order to increase the dispersion of a cone speaker it is necessary to make the physical size of the cone speaker as small as possible so that the speaker acts as a "point" source. Unfortunately, small speakers have limited power handling capability.

Loudspeakers employing metallic ribbons and plastic or paper diaphragms to reproduce sounds are also well-known in the art and have been demonstrated to have advantages compared to the cone speakers. In particular, such speakers may have better dispersion characteristics than the cone speakers for a given power handling capability because they approximate a "line" source rather than a "point" source. Unfortunately, due to the mechanical characteristics of the metallic ribbons and non-metallic panels and unfortunate acoustical design, such speakers often have mechanical resonances or other distortions which prevent the speakers from producing an accurate reproduction of the sound with high resolution over the full acoustic frequency range normally encountered during high-fidelity sound reproduction. For example, such speakers are often subject to a phenomenon known as "diffraction" which occurs when, due to poor speaker design, the speaker acts as a multiple line source instead of a single line source. In addition, the non-metallic materials used to fabricate panel speakers were subject to deterioration with age due to stretching of the speaker materials.

In order to achieve good frequency response, especially in mid-range frequencies, it has been found necessary to use a long, narrow lightweight ribbon. Prior art ribbon midrange tweeter designs have been unable to properly align such a ribbon with the speaker's magnetic field and to keep the ribbon centered within its supporting frame for relatively high power levels. Previous prior art ribbon designs have not demonstrated the capability to reproduce music at lifelike sound power levels.

In addition, prior art ribbon transducer designs have not been able to minimize the acoustical leakage around the sides of the ribbon or provide for the proper electrical and dynamic characteristics of the acoustical ribbon element. Further, prior art ribbon systems have often utilized classical cone-type woofers instead of ribbon woofer elements due to problems encountered in the design of large area ribbons necessary for low-frequency response. The cone-type woofers were subject to the distortion and dispersion problems set forth in detail above.

Therefore, it is an object of the present invention to provide a speaker system which provides accurate, high-resolution reproduction of sound over the full acoustic frequency range normally encountered in sound reproduction systems. It is a further object of the present invention to produce a speaker system with excellent dispersion over the full acoustic frequency range.

It is yet another object of the invention to produce a ribbon speaker system which is easily constructed from readily available materials.

It is yet another object of the invention to produce a ribbon speaker system which eliminates the mechanical resonances and distortions typically found in prior art cone, planar and ribbon speakers.

It is yet a further object of the invention to provide a speaker system in which the transducers are not subject to deterioration with age.

It is still another object of the invention to provide a speaker system with means for automatic centering of the speaker ribbons within their supporting framework.

It is another object of the invention to provide a speaker with a wide bandwidth frequency response.

It is yet another object of the invention to provide a tweeter transducer which acts like a theoretical "line source".

It is a further object of the invention to provide a
line source tweeter transducer which utilizes only a single common magnetic structure and no back wave damping materials.

According to the invention, the foregoing problems are solved and the foregoing objects are achieved by an electromagnetic transducer (100) for reproducing sound having a rigid, supporting frame (140, 270, 271, 275, 285, 286, 290, 780, 781, 850, 856, 890, 985, 986) magnetic apparatus (277, 278, 739, 741, 744, 753, 839, 841, 844, 853) attached to the frame to generate a magnetic field across the frame, an elongated, narrow, planar electrically-conductive ribbon (150, 160, 250, 260, 450, 460, 760, 850, 950, 1050) suspended in the magnetic field by attachments (921, 954, 1021, 1084) at the top and bottom of the ribbon, the plane of the ribbon being parallel to the direction of the field, characterized in that the magnetic apparatus further comprises means (839, 841, 844, 853, 876, 883) for imparting to said magnetic field an intensity that increases in a direction extending perpendicular to the plane of the ribbon on either side of the center position, including a pair of magnets (739, 741, 839, 841) located along one edge of the ribbon, a pair of magnets (744, 753, 844, 853) located along the opposite edge of the ribbon and a gap or a nonmagnetic spacer (782, 784, 883, 876) located between each pair of magnets at the ribbon center position in the same plane as the ribbon, the resulting magnetic field urging the ribbon toward the center position in a direction perpendicular to the ribbon plane when the ribbon deviates from the center position in either direction.

Further features and advantages of the invention will be apparent from the following detailed description and accompanying illustrative, non-limitative drawings wherein

Figure 1 shows an isometric view of the integrated three element ribbon transducer with a cut-away portion illustrating the placement of the magnets and ribbons.
Figure 2 shows a cross-section of the speaker at sections lines 2—2 in Figure 1.
Figure 3 is an enlarged view of the woofer section of Figure 2.
Figure 4 is a front view of the three-element transducer with the acoustic cover removed to expose the ribbons and supporting frame arrangement.
Figure 5 is an enlarged view of the woofer ribbon showing the placement of the horizontal cuts.
Figure 6 is a cross-section enlarged view of the woofer transducer taken along line 6—6 in Figure 4.
Figure 7 is an enlarged isometric sectional view of the midrange transducer.
Figure 8 shows an enlarged isometric sectional view of the tweeter transducer.
Figure 9 is an isometric sectional view of the upper end of the tweeter transducer showing the attachment of the ribbon.
Figure 10 is an isometric sectional view of the lower end of the tweeter transducer showing the attachment of the ribbon.

A perspective view of an illustrative three-element transducer suitable for use in the ribbon speaker system is shown in Figure 1. Transducer 100 has a generally planar shape and is mounted upright on flat base member 101. Transducer 100 is only a single transducer; for a conventional stereophonic sound reproduction system, two transducers would be placed at separate points in the listening area. When two transducers are used their mechanical construction is nearly identical with the exception of symmetrical changes in ribbon element shape as will be discussed in more detail hereinafter.

An illustrative size for transducer unit 100 is approximately 80 inches (203.2 cm) tall and approximately 36 inches (91.4 cm) wide. The mechanical structure of the woofer portion of the unit consists of two upright support members (not shown in Figure 1) which are structurally attached to the bottom member 102 and to top member 135. One support member is perpendicular to the base 102 and the other support member is mounted at an angle to base member 102. A stretcher element 146 is mounted on one upright support member and another stretcher element 146 is mounted on the other upright support member, respectively.

A thin, aluminum ribbon 120 of trapezoidal shape, which conducts a current varying in proportion to the audio frequencies to be reproduced, is attached on each vertical edge to a respective stretcher element and held in tension between stretcher elements by a spring mechanism (not shown). Ribbon element 120 is supported in a magnetic field produced by a trapezoidal array of permanent magnets 130 mounted on a backing plate 125 attached to the support members. Actual sound generation by the woofer transducer is produced by audio-frequency vibrations of ribbon 120 caused by D’Arsonval forces in turn created by an interaction of the current running in ribbon 120 with the magnetic field produced by magnet array 130.
Transducer 100 is covered with acoustically-transparent fabric 105 to improve appearance and to help protect ribbon element 120 (In Figure 1, a portion of fabric 105 has been cut away from the front of transducer 100 to reveal the internal construction). Detailed construction of the woofer magnet array and transducer ribbon are shown in Figures 3—6 inclusive.

Also shown in Figure 1 are the mid-range and tweeter transducer units suitable for use with the illustrative embodiment of the speaker system. Each tweeter transducer consists of two side plates (only plate 140 is shown in Figure 1) bearing two sets of magnets which establishes magnetic field between them. Located between the two sets of magnets is a narrow rectangular ribbon transducer 150 which is made of a light gauge tempered aluminum with horizontal corrugations. The top and bottom ends of the ribbon are attached to the side plates as will be herein-
after described. The vertical edges of ribbon 150 are not attached to the support. Construction details of the magnet array and ribbon are shown in Figure 8.

The midrange transducer unit also consists of two side plates (not shown in Figure 1) bearing two sets of magnets which establish a magnetic field between them. Located between the two sets of magnets is a narrow rectangular ribbon transducer 160 which is made of a light gauge tempered aluminum. The top and bottom ends of the ribbon are attached to side plates (as with the tweeter ribbon) as will hereinafter be described. However in contrast to the tweeter element, the vertical edges of the mid-range element are fastened to the vertical side plates by acoustical foam. In addition, the ribbon is corrugated at an angle to its longitudinal axis rather than horizontally. Construction details of the mid-range magnet array and ribbon are shown in Figure 7.

The transducer assembly is completed by an "ear" 103 which is located next to the woofer transducer and serves as an acoustic baffle.

Figure 2 of the drawing shows a sectional view of the three-element transducer taken at the line 2—2 in Figure 1. Bottom member 202 and top member (not shown) each consist of a piece of sheet steel approximately 3/16" (0.45 cm) by 3" (7.62 cm) by 35" (88.9 cm) in length and are used to hold the various speaker elements in position. Mounted on bottom member 202 are the main support members 210 and 211 comprised of 1" (2.54 cm) wood particle board or other suitable material. Support members 210 and 211 are approximately four inches (10.16 cm) by one inch (2.54 cm) in cross-section and are held in a fixed spatial relationship by backing plate 225 (which is bolted to the front of each support member) and nine back braces, 236, of 1" (2.54 cm)x3/16" (0.45 cm) steel which are bolted to the back of support members 210 and 211. Two of the strips run vertically along support members 210 and 211 and the rest run horizontally between the members with equidistant spacing. Backing plate 225 is a planar, trapezoidal-shaped steel plate of 0.105 inch (0.26 cm) thickness which extends over the entire height of the transducer. It is uniformly perforated with 1/4-inch (0.63 cm) perforations.

Cemented to the outside face of backing plate 225 with epoxy cement is an array of permanent magnets 230. Each of these magnets consists of a barium-strontium ferrite ceramic magnetic material 1.25 (6.35 cm) by 0.75 (1.90 cm) by 0.44 (1.11) cm thick. Magnets 230 are mounted on backing plate 225 with their north/south axis perpendicular to the plane of plate 225. In addition to providing physical support, plate 225 also provides a path of low magnetic reluctance to complete the magnetic circuit. Across each magnet row, the individual magnets are mounted in a consistent relationship so that a north pole or a south pole occurs across the width of the magnetic array (shown in detail in Figure 6). The magnet pole positions in each magnet row are reversed in the magnets in the rows vertically above and below it (shown in detail in Figure 6). This magnet arrangement creates a series of horizontal magnetic field patterns with vertically alternating magnetic field direction.

Sound-generating ribbon element 220 consists of a corrugated aluminum ribbon which is supported on all four sides. In particular, as shown in Figure 2, ribbon 220 is held in tension between two stretcher members 245 and 246. Member 245 is permanently mounted to support 211. Member 246, however, slides along the face of support 210 and can be held in tension by means of tensioning screws and springs 252.

Located next to the woofer transducer are the mid-range transducer and the tweeter transducer. Both transducers consist of similar construction. The mid-range transducer consists of a supporting frame and parallel rows of magnets. The supporting frame, in turn, consists of side plates 270 and 271 which are held rigidly separated by a plurality of 19 braces, 275. Attached, by epoxy cement, to plates 270 and 271 are sets of magnets 277 and 278, respectively. Magnet sets 277 and 278 establish the magnetic field which interacts with the current running in ribbon 280 to generate sound producing vibrations. In order to prevent acoustical energy from escaping around ribbon 260, the vertical edges of ribbon 260 are cemented to corner pieces 280 and 281.

The tweeter transducer also consists of a supporting framework comprised of plates 285 and 288 held separated by braces 290. In contrast to the mid-range transducer, however, the edges of ribbon 290 are not attached to a side-supporting structure. In addition, ribbon 290 is much narrower than ribbon 260.

The transducer unit is also provided with an ear or baffle unit comprised of members 203 and 215 and separator 207 which unit prevents sound energy emanating from the rear of the woofer unit from interfering with sound energy projected from the front of the transducer. The baffle extends the basic response of the transducer to lower bass frequencies and can be illustratively comprised of wood or particle-board material. A wooden cap, 295, is mounted at each end of the transducer to provide a smooth corner and an attractive appearance. As previously mentioned, the entire transducer unit is covered with acoustic fabric 205 to improve its appearance.

Figure 3 shows an illustration of the construction of the acoustical transducer members. In particular, Figure 3 shows support members 310 and 311 which, as previously mentioned, are rigidly separated by backing plate 325 and back braces 336. Also shown are stretcher members 345 and 346 which are used to support and tension ribbon elements 320. Stretcher member 345 is comprised of two wooden strips 331 and 335, having a rabbet 337 cut in each. Strip 335 is permanently attached to support 311 by glue and screws. Strips 335 and 331 are bolted together by bolts 374 and "T-nuts" 351 at regular intervals. When strips 335 and 331 are fastened together,
the opposing rabbets form a slot to hold a U-shaped strip of soft foam 333. Ribbon 320 is fastened between strips 335 and 331 by silicone rubber adhesive. Strip 331 has rounded corners to reduce diffraction of sound waves produced by ribbon 320 which can be caused by sharp edges in the vicinity of the ribbon.

Stretcher member 346 is similarly composed of two wooden pieces bolted together by T-nut 373, forming a clamp into which is inserted transducer ribbon 320. Stretcher unit 346, however, is not fastened to support member 310 but is free to move in a direction of arrow 396. Ribbon 320 is held under tension by means of a screw arrangement which forces structure member 346 to the right in Figure 3. In particular, a metal angle iron 383 is mounted to main support 310 by means of screws 361. Angle iron 363 has a hole drilled in it through which is inserted tensioning bolt 352 and tensioning spring 365. A plurality of tensioning bolts is spaced evenly along the edge of stretcher member 346. Each of the bolts 352 threads into a corresponding barrel nut 379 which is recessed into stretcher member 346. After the transducer unit has been assembled, bolts 352 are tightened to compress tensioning springs 365, which, in turn, provide a uniform horizontal tension to ribbon 320. Springs 365 ensure that the ribbon will maintain its originally-manufactured frequency response despite small changes in the supporting structure. To prevent stretcher 346 from moving away from support 310, a plurality of holes (not shown) are drilled through stretcher 346. Through these holes screws are inserted into support 310. A rubber grommet around each screw allows the tension adjustment to be made after stretcher member 346 is attached to support 310.

Figure 3 also shows in more detail the orientation of magnets 330 which are cemented to backing plate 325. The magnetic axis of each magnet is arranged to be perpendicular to backing plate 325 and the magnets are arranged with north and south poles as is shown in Figure 6 to produce a magnetic force field as shown at 680.

Figure 4 shows a plan view of the three-element transducer showing in detail the shape of the sound-generating ribbon. In particular, ribbon 420 has a trapezoidal shape which is approximately 10 inches (25.4 cm) wide at its top 462 and 14 inches (35.56 cm) wide at its bottom 464. Ribbon 420 is slightly corrugated at approximately 0.200 inch (0.51 cm) intervals to produce corrugations with approximately 0.060 inch (0.15 cm) height peak-to-peak in order to increase the pliability of the ribbon material. The trapezoidal shape of the ribbon distributes its natural frequency resonances over a wider frequency range than the frequency band of a simple rectangular ribbon.

Ribbon 420 is mounted in a trapezoidal frame consisting of support members 445 and 446, base 402 and top member 435. As previously mentioned, ribbon 420 is supported and tensioned between stretcher members 445 and 446. Figure 4 shows a transducer unit which would be used as the left transducer in a two transducer sound system. The right transducer would be identical in construction to the left transducer except that it is a mirror image.

Ribbon 420 has a plurality of narrow horizontal, alternating slots 432, 434 which divide it into a single electrical current path. In particular, as shown in more detail in Figure 5, a plurality of equally-spaced narrow slots 534 are provided which extend horizontally from the right side of ribbon 520 nearly to the left side. Interspersed with slots 534 are a plurality of horizontal slots 532 which extend horizontally from the lefthand side of ribbon 520 nearly to the righthand side. These slots divide the entire ribbon surface into a single serpentine current path in which the current follows arrows 537 (during the negative half cycle of the alternating current drive current flows in the reverse direction to arrows 537). Slots 532 and 534 ensure that the current will follow a plurality of substantially horizontal paths to ensure proper interaction with the magnetic field produced by the magnet array located directly behind the ribbon.

Also shown in Figure 4 are the mid-range ribbon 460 and the tweeter ribbon 450. Mid range ribbon 460 is approximately 2.2 inches (5.59 cm) wide and is also corrugated at 0.2 inch (0.51 cm) intervals. These corrugations are at a variable angle to the vertical axis of the ribbon. Specifically, the slant angle of the corrugations varies uniformly over the length of the ribbon so that the flute length L1 at the top of the ribbon is approximately 12 inches (30.48 cm) and the length L2 at the bottom of the ribbon is 81/2 (21.59 cm)—9 (22.86 cm) inches.

Tweeter ribbon 450 is approximately 0.5 inches (1.27 cm) in width and is uniformly corrugated horizontally at 0.1 inch (0.25 cm) intervals.

Figure 6 shows a vertical section of the ribbon and magnet array, in particular showing slots 634 in ribbon 620. Pieces of tape 638, (preferably made of a polyester material manufactured by Dupont De Nemours and known by the Registered Trademark Mylar tape) is placed over each slot to provide mechanical integrity for the ribbon. As shown in Figure 6, slots 634 are physically located with respect to magnet rows 630 so that the horizontal current-carrying portions of ribbon 620 are located over the gaps between magnet rows where the magnetic field is strongest. The current direction reversals caused by slots 634 correspond to the magnetic field reversals which are caused by the reversed pole positions in alternate magnet rows as shown in Figure 6. This arrangement ensures that the entire ribbon moves in the same direction simultaneously. Figure 6 also shows the location of braces 636 bolted to support 611. Magnets 630 are cemented on backing plate 625 at 2 inch (5.1 cm) intervals.

Figure 7 shows an isometric section of the illustrative mid-range transducer. The main components of the mid-range unit are ribbon 760 and its supporting frame. Ribbon 760 is an elongated
rectangular tempered aluminum ribbon of approximately 0.7 mil (0.07 cm) thickness, 80 inch (203.2 cm) length and 2.2 inch (5.59 cm) width. Ribbon 760 is corrugated across its width at approximately 0.2 inch (0.51 cm) intervals with corrugations of approximately 0.1 inches (0.25 cm) peak-to-peak. As previously described the corrugations are at a variable angle relative to the vertical axis of the ribbon in order to provide a variable spring support in line with the acoustical drive and to provide mechanical crosswise stiffness. The magnet supporting structure is formed of flat steel side pieces 770 and 771 approximately 3 inches (7.62 cm) wide by 3/16 inches (0.48 cm) thick. Side pieces 770 and 771 are rigidly secured at approximately a 4.5-inch (11.43 cm) spacing by 19 spacer bars 775 spaced equally over the height of the transducer (approximately 4-inch (10.16 cm) intervals). Spacer bars 775 are constructed of a magnetic material and provide a return path for the magnetic field generated by the magnets 739, 741, 744 and 753 in addition to providing mechanical spacing. Each end of bars 775 is threaded to accept a cap screw 726 in order to secure the bars to the side plates 770 and 771.

A set of magnets 739 and 741 are mounted on the inside face of side plate 770 as shown in Figure 7. Each magnet set is comprised of three magnets, each of which, in turn, consists of barium-strontium ferrite ceramic magnetic material and is approximately 17/8 (4.78 cm) by 7/8 (2.24 cm) by 9/8 (0.97 cm) in size. The magnets are spaced uniformly along the height of the transducer.

In accordance with the invention, magnet pair 739 and 741 are separated by an air gap or other suitable non-magnetic spacer 782. Spacer 782 is approximately 1/8 inch (0.33 cm) in thickness and helps to shape the magnetic field produced by magnets 739 and 741 which shaping, in turn, helps to keep ribbon 760 physically centered.

Attached to side member 771 are also two magnet sets, 744 and 753 arranged in a similar fashion to magnets 739 and 741 with the exception that the poles of opposite polarity face ribbon 760. Magnets 744 and 753 are also separated by a non-magnetic spacer or gap 784.

Two wooden strips 780 and 781 are mounted on the lateral faces of the magnets to provide anti-diffraction exit shapes which minimize the effects of diffraction which can occur at any sharp corners located in the vicinity of sound-generating ribbon 760. To prevent acoustic energy from leaking around ribbon 760 the vertical edges of the ribbon are affixed to strips 760 and 781. In particular, ribbon 760 is attached to the inside edges of strips 780 and 781 means of pressure-sensitive-adhesive covered foam strips 772.

Figure 8 shows an isometric section of the illustrative tweeter transducer. As with the mid-range unit, the main components of the tweeter unit are ribbon 850 and its supporting frame. Ribbon 850 is an elongated rectangular tempered aluminum ribbon of approximately 0.5 (0.05 cm)—0.7 (0.07 cm) mil thickness, 80 inch (203.2 cm) length and 1/2 inch (1.27 cm) width. Ribbon 850 is corrugated across its width at approximately 0.1 inch (0.25 cm) intervals with corrugations of approximately 0.030 inches (0.08 cm) peak-to-peak to provide a soft spring support in line with the acoustical drive and to provide mechanical crosswise stiffness. The ribbon supporting structure is formed of flat steel side pieces 885 and 886 approximately 2 inches (5.08 cm) wide by 3/16 inches (0.48 cm) thick. Side pieces 885 and 886 are rigidly secured at a fixed 2 3/8 inch (6.03 cm) spacing by 13 spacer bars 890 spaced equally over the height of the transducer. Spacer bars 890 are constructed of a magnetic material and provide a return path for the magnetic field generated by the magnets 839, 841, 844 and 853 in addition to providing mechanical spacing. Bars 890 are attached to side plates 885 and 886 in the same manner as the mid-range transducer.

Two sets of magnets 839 and 841 are mounted on the inside face of side plate 885 as shown in Figure 8. Each of these magnet sets consists of three magnets, each, in turn, consisting of barium-strontium ferrite ceramic magnetic material and is approximately 1 (2.54 cm) by 1/2 (1.27 cm) by 1/4 (0.635 cm) inches in size. The magnets are spaced uniformly along the height of the transducer.

In accordance with the invention, magnet pairs 839 and 841 are separated by an air gap or non-magnetic spacer 883. Spacer 883 is approximately 1/8 inch (0.33 cm) in thickness and helps to shape the magnetic field produced by magnets 839—841 which shaping, in turn, helps to keep ribbon 850 physically centered in the gap between the magnets and prevents ribbon 850 from moving in a direction perpendicular to its plane out of the magnetic field.

Attached to side member 886 are also two magnet sets 844 and 853 arranged in a similar fashion to magnets 839 and 841 with the exception that the poles of opposite polarity face ribbon 850. Magnets 844 and 853 are separated by a non-magnetic spacer 876 as previously described to provide magnetic field centering of ribbon 850.

In the final assembly of the speaker, two wooden strips with rounded corners (not shown) are mounted on the lateral faces of the magnets to provide anti-diffraction exit shapes which minimize the effects of diffraction which can occur at any sharp corners located in the vicinity of sound-generating ribbon 850.

In addition a pair of flat ribbon conductors 840, 842 comprised of Mylar-coated aluminum foil are cemented to the faces of magnets 839, 841 and 844, 853, respectively. Aluminum conductors 840 and 842 provide a return path for the audio-frequency current flowing through ribbon 850. In particular, current flows through ribbon 850 and is split between conductors 840 and 842 and flows back up along the magnet faces to the power source. Current flow in conductors 840 and 842 provides for an electromagnetic force to aid in physical centering of ribbon 850 in a direction
parallel to its plane and prevent ribbon 850 from touching the magnet faces.

Figure 9 shows an illustrative method of attaching the top end of the tweeter ribbon element to its respective frame members. An insulating bracket 921 with an approximately 1/2-inch (1.27 cm) square cross-section is mounted between the side plates 985 and 986. The sound generating ribbon, 950, is held between bracket 921 and a copper bus bar 954 which is bolted to the bracket. At the upper end of the tweeter element the conductors 940 and 942 are also electrically connected to ribbon 950 and held by bus bar 954.

Figure 10 shows an illustrative method of attaching the bottom end of the tweeter ribbon element to its respective frame members. As with the top end, an insulating bracket 1021 is used. However, the ribbon 1050 is mounted on one side of bracket 1021 by bus bar 1054 and conductors 1040 and 1042 are mounted on the opposite side to prevent a short circuit across the speaker. The audio drive is connected between bus bar 1054 and conductors 1040 and 1042.

An alternative embodiment of the ribbon speaker system incorporates a "line source" tweeter transducer—the woofer and mid-range elements remain unchanged as previously described. The alternative tweeter transducer is implemented by mounting a second tweeter ribbon of the same size and characteristics as previously described with the first embodiment above, approximately 3/8 inch (0.93 cm) forward of the tweeter ribbon shown in Figures 9—10. The supporting structure and magnet arrangement remain the same as with the previous embodiments. The method of mounting the second ribbon is the same as previously described, that is, the ribbons may be separated by insulating bars about 3/8 inch (0.93 cm) thick and clamped by conductive bars such as bar 954 and 1054 shown in Figures 9 and 10. As with the single tweeter ribbon and the return current carrying conductor tapes in the previous embodiment, the two tweeter ribbons are electrically connected at one end so that the alternating current which drives the ribbons flows in opposite directions in each ribbon. In addition, the return conductor tapes 940, 942 in Figure 9 and 1040 and 1042 in Figure 10 are moved to the front faces 971 and 972, respectively of the magnet sets.

With this alternative embodiment, the acoustic signal from the front and back of the speaker has the same phase and the tweeter acts substantially as a "line source". Acoustical theory states that the highest quality of reproduced sound is achieved by the use of point source or line source speaker systems. Therefore, this alternative embodiment enhances the sound quality generated by the tweeter transducer.

Claims

1. An electromagnetic transducer for reproducing sound having a rigid, supporting frame, magnetic apparatus attached to the frame to generate a magnetic field across the frame, an elongated, narrow, planar electrically-conductive ribbon suspended in the magnetic field by attachments at the top and bottom of the ribbon, the plane of the ribbon being parallel to the direction of the field, characterized in that the magnetic apparatus further comprises means for imparting to said magnetic field an intensity that increases in a direction extending perpendicular to the plane of the ribbon on either side of the center position, including a pair of magnets located along one edge of the ribbon, a pair of magnets located along the opposite edge of the ribbon and a gap or a non-magnetic spacer located between each pair of magnets at the ribbon center position in the same plane as the ribbon, the resulting magnetic field urging the ribbon toward the center position in a direction perpendicular to the ribbon plane when the ribbon deviates from the center position in either direction.

2. An electromagnetic transducer according to claim 1, characterized in that said pair of magnets (277, 278, 739, 741, 744, 753, 839, 841, 844, 853) are aligned in a parallel fashion with corresponding pole positions.

3. An electromagnetic transducer according to claims 1 or 2 characterized in that the magnetic apparatus (277, 278, 739, 741, 744, 753, 839, 841, 844, 853) includes centering apparatus (840, 842, 940, 942, 1040, 1042) which generates an electromagnetic field that centers the ribbon (150, 160, 250, 260, 450, 460, 760, 850, 950, 1050) between the pairs of magnets in a direction parallel to its plane.

4. An electromagnetic transducer according to claim 3 characterized in that the centering apparatus is electrical conductors (840, 842, 940, 942, 1040, 1042) located on both sides of the ribbon (150, 160, 250, 260, 450, 460, 760, 850, 950, 1050) and positioned in planes perpendicular to the plane of the ribbon.

5. An electromagnetic transducer according to one or more of the preceding claims characterized in that the ribbon (150, 160, 250, 260, 450, 460, 760, 850, 950, 1050) is mechanically corrugated in a direction at an angle to its length.

6. An electromagnetic transducer according to claim 5 characterized in that the angle of the corrugations in the ribbon (150, 160, 250, 260, 450, 460, 760, 850, 950, 1050) varies along the ribbon length.

7. An electromagnetic transducer according to one or more of the preceding claims characterized in that a second ribbon is suspended in the magnetic field and positioned parallel to the first ribbon (150, 160, 250, 260, 450, 460, 760, 850, 950, 1050) and directly in front of the first ribbon, the ribbons being electrically connected so that current in one ribbon flows in the opposite direction to the current flow in the other ribbon.

Patentansprüche

1. Elektromagnetischer Wandler zur Tonwiedergabe, mit einem starren Tragrahmen, an den eine
magnetische Einrichtung zur Erzeugung eines Magnetfeldes über den Rahmen angebracht ist, mit einem länlichen, schmalen, ebenen, elektrisch leitfähigen Band, das im Magnetfeld mittels an der Ober- und Unterseite des Bandes vorgesehener Befestigungselemente aufgehängt ist, wobei die Ebene des Bandes parallel zur Feldrichtung verläuft, dadurch gekennzeichnet, daß die magnetische Einrichtung weiters mit einer Einrichtung versehen ist, welche dem Magnetfeld eine Intensität verleiht, die in einer quer zur Bandebene verlaufenden Richtung zu beiden Seiten der Mitte ansteigt, und ein Paar entlang des einen Bandrandes angeordnete Magnete, ein Paar entlang des gegenüberliegenden Bandrandes angeordnete Magnete und jeweils einen Spalt oder einen unmagnetischen Abstandshalter zwischen jedes Magnetpaar in der Bandmitte sowie in derselben Ebene wie das Band aufweist, wobei das resultierende Magnetfeld auf das Band eine in einer zur Bandebene senkrechten Richtung zur Mittelstellung wirkende Kraft ausübt, wenn das Band aus der Mittelstellung nach der einen oder anderen Seite ausgelenkt ist.

2. Elektromagnetischer Wandler nach Anspruch 1, dadurch gekennzeichnet, daß das Magnetpaar (277, 278, 739, 741, 744, 753, 839, 841, 844, 853) parallel zu den entsprechenden Polstelzen ausgeführt ist.

3. Elektromagnetischer Wandler nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die magnetische Einrichtung (277, 278, 739, 741, 744, 753, 839, 841, 844, 853) eine Zentriereinrichtung (840, 842, 940, 942, 1040, 1042) aufweist, die ein elektromagnetisches Feld erzeugt, das das Band (150, 160, 250, 260, 450, 460, 760, 850, 950, 1050) zwischen den Magnetpaaren in einer zu seiner Ebene parallelen Richtung zentriert.


7. Elektromagnetischer Wandler nach einem oder mehreren der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß im Magnetfeld ein zweites Band aufgehängt ist, das parallel zum ersten Band angeordnet ist, wobei die Bänder derart miteinander elektrisch verbunden sind, daß der durch das eine Band fließende Strom in der Gegenrichtung zum Stromfluß im anderen Band fließt.

Revidierungen

1. Transductor elektromagnetique servant à reproduire un son et comportant un châssis de support rigide, un dispositif magnétique fixé au châssis de manière à produire un champ magnétique qui traverse le châssis, un ruban électronconducteur plat, étroit, et allongé suspendu dans le champ magnétique au moyen d’organes de fixation situés à la partie supérieure et à la partie inférieure du ruban, le plan du ruban étant parallèle à la direction du champ, caractérisé en ce que le dispositif magnétique comporte en outre des moyens pour conférer audit champ magnétique une intensité qui augmente dans une direction perpendiculaire au plan du ruban, sur l’un ou l’autre des côtés de la position centrale, et incluant un couple d’aimants disposés le long d’un bord du ruban, un couple d’aimants situés le long du bord opposé du ruban et un interstice ou une entretoise a magnétique située entre chaque couple d’aimants au niveau de la position centrale du ruban, dans le même plan que ce dernier, le champ magnétique résultant repoussant le ruban vers la position centrale dans une direction perpendiculaire au plan du ruban lorsque ce dernier s’écarte de la position centrale dans un sens ou dans l’autre.

2. Transductor elektromagnetique selon la revendication 1, caractérisé en ce que chaque couple d’aimant (277, 278, 739, 741, 744, 753, 839, 841, 844, 853) sont alignés en tant en parallèle avec des positions de pôles correspondantes.

3. Transductor elektromagnetique selon la revendication 1 ou 2, caractérisé en ce que le dispositif magnétique (277, 278, 739, 741, 744, 753, 839, 841, 844, 853) comporte un dispositif de centrage (840, 842, 940, 942, 1040, 1042) produisant un champ électromagnétique qui centre le ruban (150, 160, 250, 260, 450, 460, 760, 850, 950, 1050) entre les couples d’aimants dans une direction parallèle à son plan.

4. Transductor elektromagnetique selon la revendication 3, caractérisé en ce que le dispositif de centrage est formé par des conducteurs électriques (840, 842, 940, 942, 1040, 1042) situés sur les deux faces du ruban (150, 160, 250, 260, 450, 460, 760, 850, 950, 1050) et disposés dans des plans perpendiculaires au plan du ruban.

5. Transductor elektromagnetique selon une ou plusieurs des revendications précédentes, caractérisé en ce que le ruban (150, 160, 250, 260, 450, 460, 760, 850, 950, 1050) possède des onductions formées mécaniquement dans une direction faisant un angle par rapport à son étendue en longueur.


7. Transductor elektromagnetique selon une
ou plusieurs des revendications précédentes, caractérisé en ce qu'un second ruban est suspendu dans le champ magnétique et est disposé parallèlement au premier ruban (150, 160, 250, 280, 450, 460, 760, 850, 950, 1050) en étant situé directement en vis-à-vis du premier ruban, les rubans étant raccordés électriquement de sorte que le courant circule dans un ruban en sens opposé du sens de circulation du courant dans l'autre ruban.