

- [54] **TRANSDUCER FOR FM SONAR APPLICATION**
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- [51] Int. Cl. **H04r 17/00**
- [58] Field of Search **310/8.2, 8.9, 9.1, 9.4, 310/9.5, 9.6; 340/8 R, 10; 73/67.7, 67.8 R**

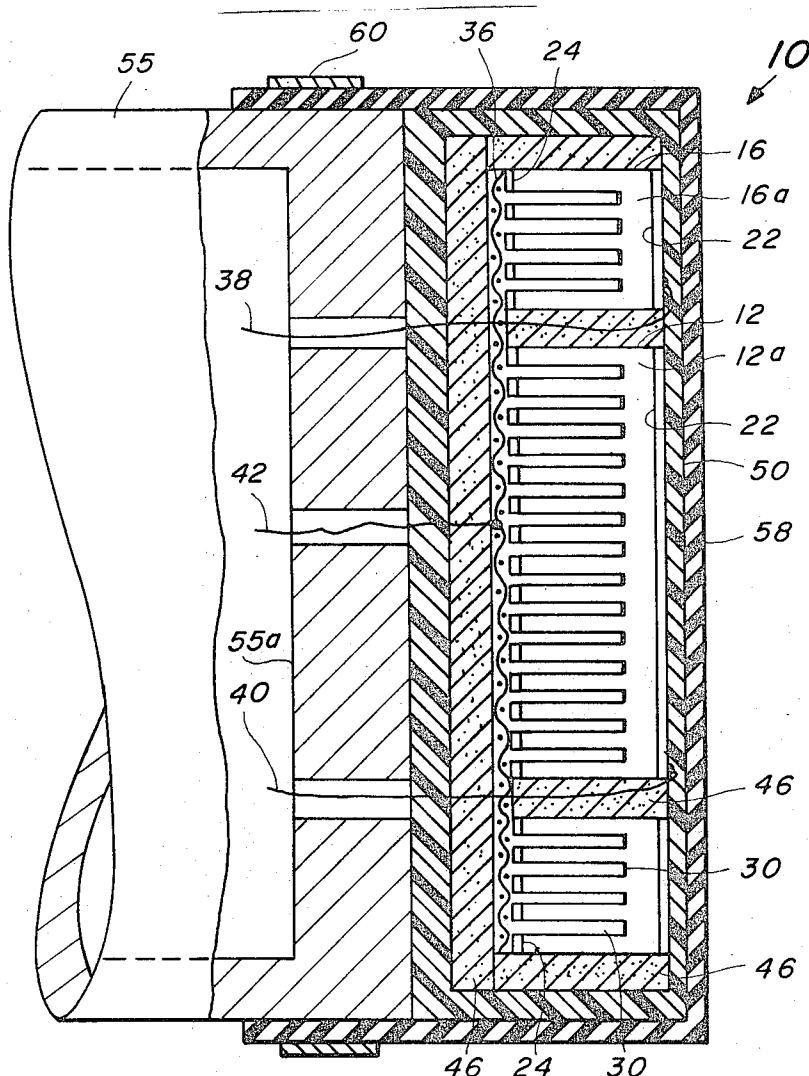
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[57] **ABSTRACT**

A narrow beam, electroacoustic sonar transducer is described that substantially reduces acoustic energy cross-coupling between projecting and receiving portions thereof during continuous F.M. use. The transducer is characterized by a pair of semi-annular piezoelectric projecting elements arranged in concentric relation to a pair of semi-circular, piezoelectric receiving elements all lying in a common plane. The reverse sides of the elements are slotted, and the spaces between the elements are filled with acoustic energy transfer barrier material. The piezoelectric elements and acoustic energy barrier material are encapsulated as an assembly in a layer of deaerated polyurethane material.

11 Claims, 3 Drawing Figures



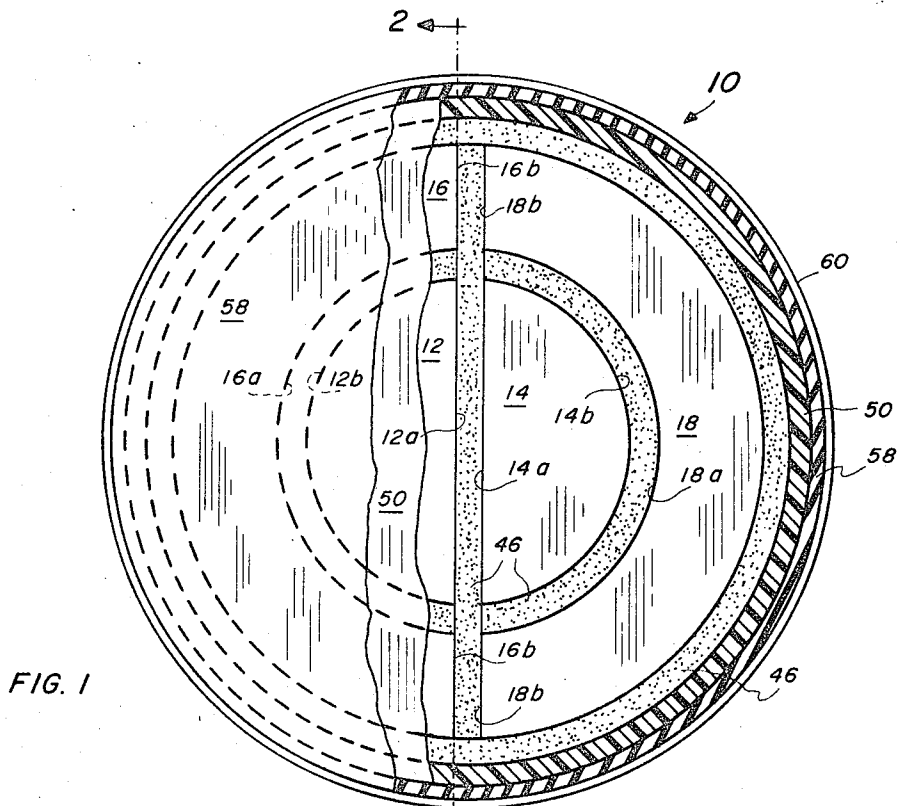


FIG. 1

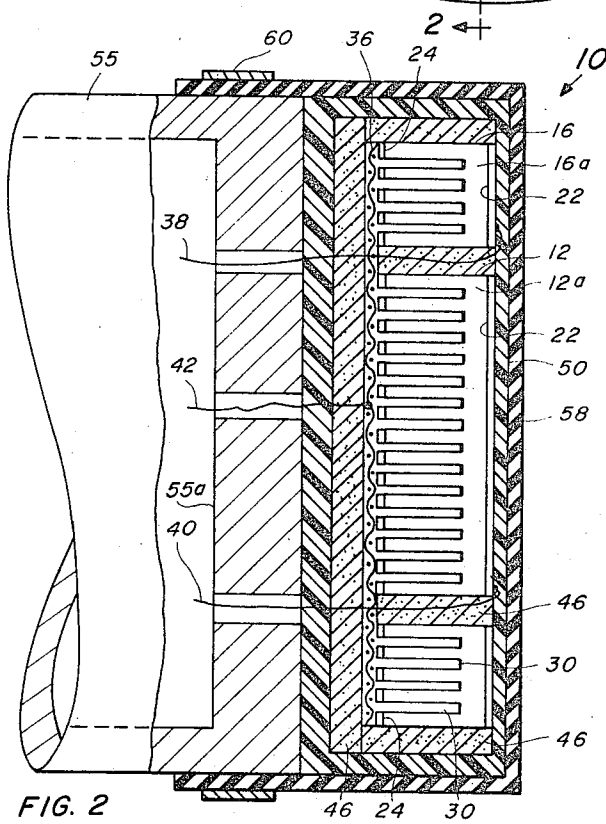


FIG. 2

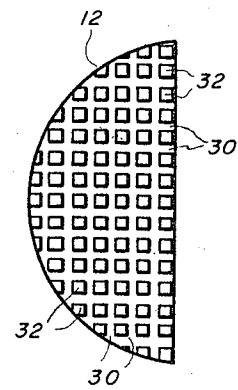


FIG. 3

TRANSDUCER FOR FM SONAR APPLICATION

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for Governmental purposes without the payment of any royalties thereon or therefor.

FIELD OF THE INVENTION

This invention relates to the conversion of energy between electrical and acoustical states, and more particularly to narrow beam, wide band, electroacoustic transducers capable of simultaneously generating and receiving acoustical energy, such as in a continuous F.M. (frequency modulated) sonar system. In this regard the invention is directed especially to the problems of reduction of what is sometimes known as "cross-talk" between the electroacoustic elements. For purposes of this specification, the term "cross-coupling" will be used as being more descriptive of the detrimental condition that is sought to be reduced. Thus, cross-coupling will be considered to be the transfer of acoustical energy from a projecting element to a receiving element through a path or paths other than the primarily intended projection and reception paths to and from a reflecting target. Cross-coupling therefore includes mechanical transfer of energy through the element supporting structures, through the elements themselves, and/or through the surrounding environment.

DISCUSSION OF THE PRIOR ART

Various narrow beam electroacoustic transducer devices have been proposed that utilize separate projecting and receiving elements in a unitary structure, often with the elements of circular or annular configuration and mounted concentrically in an effort to achieve efficient narrow beam transmission and reception. Examples of such devices are found in U.S. Pat. Nos. 3,109,112 of R. A. Lester, 3,327,286 of J. A. Dorr et al, and 3,457,543 of O. L. Akervold et al. None of the known narrow beam projecting and receiving transducers, however, are satisfactory for use in a continuous F.M. sonar system because of signal degradation due to cross-coupling. Of course, the problem of cross-coupling or cross-talk is minimized or avoided when such transducers are used in pairs to transmit and receive two widely different frequencies, or where the transducers are used in pulsed C.W. (carrier wave) systems such as in depth sounders or wave height measuring devices wherein the projecting and receiving duties of the transducer are alternated. Accordingly, most of the prior art effort in narrow beam electroacoustic projecting and receiving transducers has been toward improving resolution, as by suppression of side lobes and enhancement of main lobes. This has left a gap or need in the electroacoustic transducer art for a narrow beam electroacoustic projecting and receiving transducer that is capable of simultaneously and continuously transmitting and receiving F.M. acoustic energy into and from a water medium with a minimum of signal degradation or loss of operating efficiency due to cross-coupling.

SUMMARY OF THE INVENTION

The invention aims to overcome most or all of the

disadvantages of the prior art in filling the need for a narrow beam, wide band, projecting and receiving electroacoustic transducer, that is notably superior for use in continuous F.M. sonar systems, through the reduction of cross-coupling, and the optimization of energy transfer through the desired paths.

Accordingly, it is a general object of the invention to provide an improved projecting and receiving electroacoustic transducer.

A more specific object of the invention is the provision of an electroacoustic transducer for projection and reception of acoustic energy by structurally associated piezoelectric projecting and receiving elements, respectively, characterized by a minimum of energy cross-coupling therebetween, whereby the transducer is more useful for continuous F.M. service in high KHz ranges than transducers available heretofore.

Another, and important, object of the invention is the provision of a novel transducer of the foregoing character that is compact and rugged in construction making it suitable for use under extreme conditions and reliable for use either alone or in large arrays.

Still another object is to provide an electroacoustic transducer for, but not limited to, continuous F.M. sonar use that exhibits substantially uniform energy transfer across a substantial frequency bandwidth.

Yet another object is the provision of a transducer structure having the mentioned features and which is characterized by a pair of semi-annular or arcuate piezoelectric transducer elements lying in a plane normal to the direction of transmission, the ends of the arcuate elements being separated by a vibrational energy transfer barrier material, and a pair of semi-circular piezoelectric elements, disposed in the same plane and in concentric relation to the arcuate pair of elements, the semi-circular elements being separated from one another and from the first pair of elements by vibrational energy transfer barrier material.

A further object of the invention is to enhance the frequency bandwidth characteristics, as well as reducing cross-coupling, of the transducers made according to the invention by dicing or slotting the rear surfaces of the pairs of piezoelectric elements, and backing the elements with energy transfer barrier material.

As another object the invention aims to provide an improved projecting and receiving transducer of continuous F.M. use that is characterized by a particularly low degree of cross-coupling between the projecting and receiving elements on the order of -35 db or less.

Other objects and many of the attendant advantages will be readily appreciated as the subject invention becomes better understood by reference to the following detailed description, when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front elevational view of a transducer embodying the invention with portions broken away to reveal other portions;

FIG. 2 is a sectional view of the transducer taken substantially along line 2-2 of FIG. 1; and

FIG. 3 is a rear elevational view of one of the piezoelectric elements of the transducer.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the form of the invention illustrated in the draw-

ings and described hereinafter, there is described an electroacoustic transducer, indicated generally at 10, that is particularly well suited for use in simultaneously projecting and receiving acoustic energy into and from an aqueous medium as part of a hand held, continuous duty, F.M. sonar system operating in a frequency range of 100 to 150 KHz, and operable as a hydrophone in a lower 24 to 45 KHz range. Such F.M. sonar systems are well known to those skilled in the art to which the invention pertains and, accordingly, description thereof is not deemed pertinent here. Suffice it to say, for the purpose of this discussion, that such systems operate at frequencies that may differ considerably from what are generally considered audible, and that the terms acoustic, electroacoustic, or the like are not to be limited to audible frequency ranges.

Transducer 10 comprises, among its salient features, two pairs of piezoelectric elements, a first pair consisting of semi-circular or half disc elements 12 and 14, and a second pair consisting of semi-annular elements 16 and 18. The first pair of piezoelectric elements 12 and 14 are arranged with their straight edge surfaces 12a and 14a in spaced parallel relation, and their curved, substantially semi-circular edge surfaces 12b and 14b, respectively, facing outwardly and lying on a circle.

The second pair of piezoelectric elements 16 and 18 are disposed with their inner curved edge surfaces 16a and 18a in concentric, spaced relation to edge surfaces 12b and 14b, respectively, of elements 12 and 14. The straight end surfaces 16b and 18b of semi-annular piezoelectric elements 16 and 18 are respectively spaced from one another with the spaces therebetween being aligned with the space between straight edges 12a and 14a of semi-disc piezoelectric elements 12 and 14. These piezoelectric elements 12, 14, 16, and 18 are conveniently formed by cutting a solid disc of ceramic piezoelectric material, such as barium titanate or the like, that has been polarized for thickness mode of operation. Thus, as shown in FIG. 3, an original disc, having a diameter equal to the desired diameter of the pair of elements 16 and 18, is cut, for example by a well known air blast and abrasive technique, into four segments having the desired configurations. The disc from which the elements are cut preferably has been provided with thin layers of electrically conductive electrode material on the opposite flat faces thereof in a manner well understood in the art. These front and rear electrode layers are illustrated respectively at 22 and 24 in FIG. 2.

Piezoelectric elements 12, 14, 16, and 18 have plane radiating and receiving surfaces on their forward, or aqueous medium facing sides, whereas the rear sides of those piezoelectric elements are diced or slotted in a rectilinear pattern, best illustrated in FIG. 3, by a plurality of intersecting slots 30. These slots are conveniently formed by means of a high speed, diamond blade saw to a depth of approximately 85 percent of the thickness of the piezoelectric elements. In the embodiment being described, slots 30 were positioned to leave square lands or posts 32 in rows and columns having center-to-center spacings of 0.115 inch. In the present example, slot widths of 0.015 inch were used, and spacings between the piezoelectric elements 12, 14, 16, and 18 of 0.065 inch. Further, in that embodiment, which was designed to be operated in a continuous transmission F.M. system in the 100 KHz to 150 KHz frequency

range, the diameter across elements 16 and 18 was about 3.50 inches, and the diameter across elements 12 and 14 was 0.68 of the diameter across elements 16 and 18, or about 2.38 inches. This ratio of the outer elements to the inner elements is important to efficient operation of transducer devices embodying the invention.

The rearwardly directed faces of the piezoelectric element posts formed by the intersecting slots 30 are provided with an electrode 36 in the form of a metal mesh or grid soldered to the free end of each post. This rear electrode may be formed of copper, nickel, or any other convenient metal or metal alloy. In the embodiment being described, electrode 36 comprises a mesh of 0.005 inch copper wire.

Suitable lead wires, such as 38 and 40, are connected to the front electrodes 22, while one or more other lead wires, such as 42, are connected to rear electrode 36.

The spaces between the respective piezoelectric elements 12, 14, 16 and 18 are filled with an acoustic energy barrier material 46. Material 46 is preferably one having good sound insulation or acoustic energy absorption characteristics, one example being the material sold under the trademark "CORPRENE". This material is readily available in sheet form. In the present embodiment the spaces 13, 17 and 19 were filled with material 46 cut from sheet stock having a thickness of 1/16 inch and cemented in place by a commercial adhesive or cement sold under the trademark "VULCALOCK." Layers of the acoustic energy barrier material 46 are also applied by cementing a strip of "CORPRENE" to the periphery of the assembled semi-annular piezoelectric elements 16 and 18, and by cementing a disc of "CORPRENE" to the rear faces of the assembled elements 12, 14, 16, and 18 over the wire mesh rear electrode 36.

Only the transmitting and receiving front surfaces of the piezoelectric elements remain free of covering with the material 46, these being the surfaces which are to be acoustically coupled to a surrounding aqueous medium when in use. To this end, these front faces of the piezoelectric elements are provided with an acoustic window comprising a layer of a substantially acoustically transparent material. This is accomplished, along with making the aforedescribed construction an integral and waterproof unit, by encapsulating or coating with a suitable acoustically transparent material 50.

The material 50 from which acoustic window layer and encapsulation is performed is preferably one that exhibits a relatively high and uniform degree of energy transmission, and a relatively low degree of energy reflectance, throughout the range of frequencies in which the transducer 10 will be operated. Such a material is exemplified by a product sold as a polyurethane potting compound under the trademark "HYSOL."

In the present embodiment, the encapsulating layer 50 of polyurethane acoustic window material is formed by mixing the two components supplied and then de-aerating the mixture before casting around the assembly of elements 12, 14, 16 and 18, the electrode mesh 36, and the acoustic energy absorbing barrier material 46. The resulting polyurethane layer 50, has a nominal thickness of 0.060 inches on the radiating and receiving surfaces of the piezoelectric elements.

The transducer assembly as thus far described is bonded by a suitable adhesive to the end wall 55a of an

aluminum housing 55 for transmitter and receiver electronics of the sonar system with which transducer 10 is intended to be used. A resiliently flexible boot 58 of an acoustically transparent, waterproof material such as Rho-C rubber is applied over the transducer assembly, and secured to housing 55 as by an encircling band 60. Application of boot 58 is facilitated if it is first lubricated with mineral oil.

Transducer 10 is characterized in its operation by a particularly low cross-coupling level of -35 db, or lower, between the projecting elements 12, 14 and the receiving elements 16, 18. The low level of cross-coupling is attributable in part to suppression of acoustic radiation, or coupling, in undesired directions. Contributing to this is the use of CORPRENE or similar isolation material 46 between and around, and behind the piezoelectric elements, the slotting or dicing of the rear faces of the piezoelectric elements to create voids between the post portions of the elements, and the interposition of the wire mesh electrode 36 between the rear faces of the piezoelectric elements and the layer of CORPRENE material therebehind. A further important factor results from the transmitting piezoelectric elements being in the form of a pair of half-discs instead of a single complete disc, and from the receiving elements being semi-annular rather than a complete annulus.

Obviously, other embodiments and modifications of the subject invention will readily come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing description and the drawings. It is, therefore, to be understood that this invention is not to be limited thereto and that said modifications and embodiments are intended to be included within the scope of the appended claims.

What is claimed is:

1. An electroacoustic transducer comprising:
first and second pairs of piezoelectric elements;
said piezoelectric elements of said first pair being substantially semi-disc shaped and presenting flat front surfaces each bounded by a straight side surface and an arcuate side surface, said piezoelectric elements of said first pair being disposed with said front surfaces in a first common plane with said straight side surfaces in adjacent, spaced, parallel relation to one another and said arcuate surfaces lying in a circle;
said piezoelectric elements of said second pair being substantially semi-annular in shape and presenting flat front surfaces each bounded by inner and outer arcuate surfaces and straight end surfaces, said piezoelectric elements of said pair being disposed in concentric relation to said first pair with said front surfaces lying in said first common plane and said inner arcuate surfaces in uniformly spaced relation to said arcuate surfaces of said piezoelectric elements of said first pair, said straight end surfaces being in spaced parallel relation to one another;
said piezoelectric elements of said first and second pairs being further characterized by flat rear surfaces lying in a second common plane;
front electrode means, on each of said front surfaces, for effecting electrical connection therewith;
rear electrode means, on said rear surfaces, for effecting electrical connection therewith; and
said piezoelectric elements each being further characterized by a plurality of intersecting slots formed

in said rear surfaces and defining a plurality of rearwardly extending posts on each of said piezoelectric elements.

2. An electroacoustic transducer as defined in claim 1, and wherein:

said rear electrode means comprises a metal mesh soldered to said rear surfaces at the end of each of said posts.

3. An electroacoustic transducer as defined in claim 2, and further comprising:

acoustic energy barrier material disposed between said straight side surfaces of said piezoelectric elements of said first pair, between said end surfaces of said piezoelectric elements of said second pair, and concentrically between said first and second pairs of piezoelectric elements.

4. An electroacoustic transducer as defined in claim 3, and further comprising:

a layer of acoustic barrier material disposed in encircling engagement with said outer arcuate surfaces of said piezoelectric elements of said second pair.

5. An electroacoustic transducer as defined in claim 4, and further comprising:

a disc-shaped layer of said acoustic energy barrier means disposed against said rear electrode means in covering relation to said first and second pairs of piezoelectric elements.

6. An electroacoustic transducer as defined in claim 5, and wherein:

said spaced end surfaces of said second pair of piezoelectric elements are aligned with said straight side surfaces of said first pair of piezoelectric elements.

7. An electroacoustic transducer as defined in claim 6, and further comprising:

electrically insulating and waterproof acoustic window means, overlying said front surfaces of said first and second pairs of piezoelectric elements and said acoustic barrier material therebetween, for effecting acoustic coupling between said front surfaces and an ambient water medium.

8. An electroacoustic transducer as defined in claim 7, and wherein:

said acoustic window means comprises a layer of substantially acoustically transparent deaerated polyurethane material.

9. An electroacoustic transducer as defined in claim 8, and wherein:

said acoustic window means further comprises a layer of substantially acoustically transparent rubber-like material.

10. An electroacoustic transducer for simultaneous projection and reception of acoustic energy into and from an aqueous medium with minimized cross-coupling, said transducer comprising:

a pair of substantially semi-disc shaped, piezoelectric projecting elements having arcuate side surfaces arranged on a first circle and straight side surfaces in parallel, spaced relation, said projecting elements being polarized for thickness excitation between front and rear surfaces thereof;

a pair of substantially semi-annular shaped, piezoelectric receiving elements having inner and outer arcuate side surfaces respectively arranged on second and third circles concentric with said first circle and straight end surfaces disposed in spaced

parallel relation to one another, said receiving elements being polarized for thickness excitation between front and rear surfaces thereof;

acoustic energy absorbing material disposed between said straight side surfaces of said projecting elements, between said straight end surfaces of said receiving elements, and between said arcuate side surfaces of said projecting elements and said inner arcuate side surfaces of said receiving elements;

said projecting and receiving elements being characterized by intersecting grooves formed in said rear surfaces and extending through a majority of the thickness of said elements so as to define a plurality of rearwardly extending, discrete posts and so as to interrupt planar vibration transmission within each of said elements;

front electrode means comprising a layer of electrically conductive material on said front surfaces of each of said piezoelectric elements;

rear electrode means comprising electrically conductive wire mesh overlying said rear surfaces and electrically bonded thereto, said wire mesh being loosely woven so as to be substantially free of vi-

bratory energy transmission from point to point thereof;

a layer of acoustic energy absorbing material disposed behind said wire mesh in loosely coupled engagement therewith;

a layer of acoustic energy absorbing material in encircling relation to said first and second piezoelectric elements;

a layer of substantially acoustically clear deaerated polyurethane compound encapsulating said projecting and receiving elements, said electrode means, and said acoustic energy absorbing material; and

conductor means, connected to said electrode means, for applying energizing electrical signals to said projecting elements and for collecting electrical signals from said receiving elements.

11. An electroacoustic transducer as defined in claim 10, and wherein:

said straight side surfaces of said projecting elements are in alignment with said straight end surfaces of said receiving elements.

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