

XR 2,927,284

TX 89013J

March 1, 1960

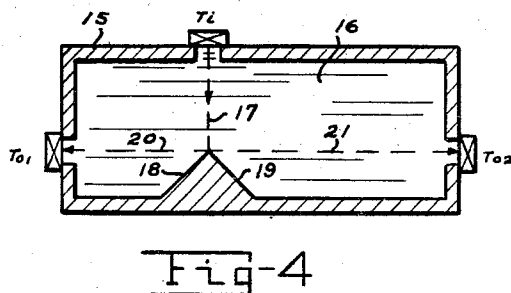
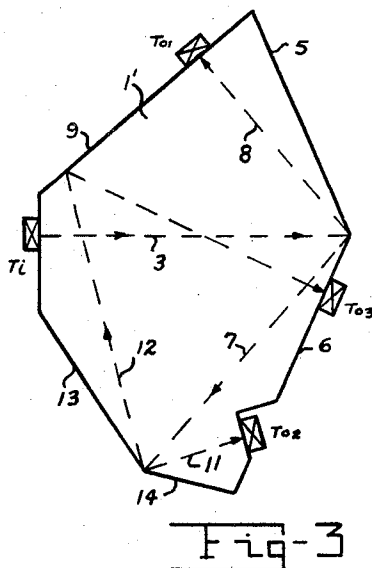
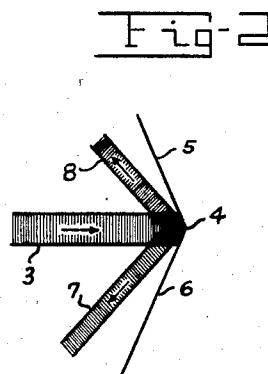
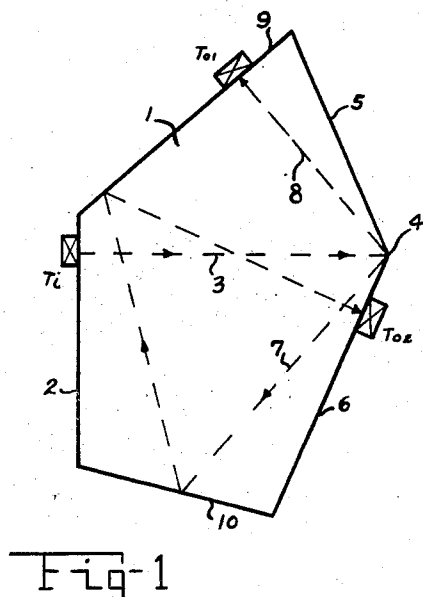
E. A. WORRELL ET AL

2,927,284

MULTIPLE PATH ULTRASONIC DELAY LINE

Filed July 18, 1958

2 Sheets-Sheet 1



INVENTORS
LEIGH L. KIMBALL
EDEL A. WORRELL
BY *Wade L. ...*
ATTORNEY
James S. Shannon
AGENT

March 1, 1960

E. A. WORRELL ET AL

2,927,284

MULTIPLE PATH ULTRASONIC DELAY LINE

Filed July 18, 1958

2 Sheets-Sheet 2

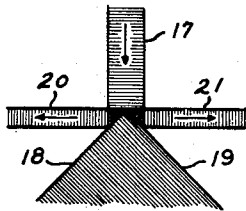


Fig-5

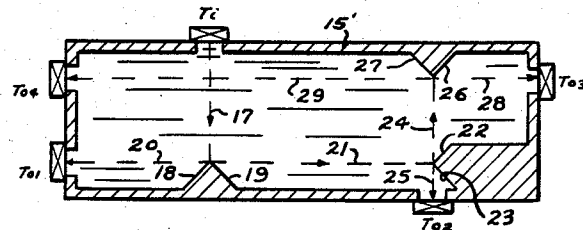


Fig-6

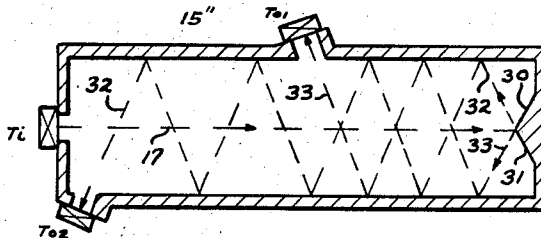


Fig-7

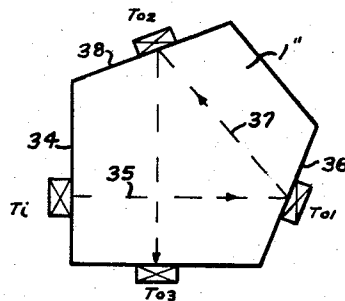


Fig-8

INVENTORS
LEIGH L. KIMBALL
EDEL R. WORRELL
BY *W. S. Shannon*
ATTORNEY
James S. Shannon
AGENT

1

2,927,284

MULTIPLE PATH ULTRASONIC DELAY LINE

Edsel A. Worrell, Baltimore, and Leigh L. Kimball, Ellicott City, Md., assignors, by mesne assignments, to the United States of America as represented by the Secretary of the Air Force

Application July 18, 1958, Serial No. 749,574

2 Claims. (Cl. 333—30)

This invention relates to electrical signal delay means of the type involving a conversion of the electrical signal into an acoustic wave, transmission of the acoustic through a suitable medium along a path having a length proportional to the delay desired, and subsequent re-conversion of the acoustic wave back into an electrical signal.

In certain electrical systems, particularly radar systems, it is frequently necessary to provide several different delay or storage times for an electrical signal. This has been accomplished in the past by using several separate delay means of the above type connected in tandem with intermediate amplification. The amplification is required because of the high power loss of the order of 20 db, accompanying conversions between electrical and acoustical energy.

The principal object of this invention is the provision of a unitary delay means providing two or more different delays with a minimum of electrical-acoustical conversions. The unitary construction together with the reduced conversion and amplification requirements results in a considerable saving in space and cost.

Briefly, a delay means in accordance with the invention comprises a single acoustic transmission medium to which is coupled an input electro-acoustical transducer and two or more output electro-acoustical transducers. In one embodiment the beam of acoustic wave energy produced by the input transducer is split by two intersecting reflecting surfaces. One branch of the split beam is directed against one of the output transducers and the other branch is directed over a path of different length to another output transducer. If more than two delays are required the second branch, instead of being directed to an output transducer, may be split to feed two output transducers over paths of different lengths, or, as before, one of these branches may be split and so on until the required number of delays is obtained. In another embodiment, the acoustic coupling between the output transducers and the acoustic wave transmission medium is made such that half the incident acoustic energy is absorbed by the transducer and half reflected to succeeding output transducers. Although each beam splitting operation is accompanied by a 3 db loss in power, there is still a considerable efficiency advantage, even after several splits, over the 20 db loss in a transducer.

A more detailed description of the invention will be given with reference to the accompanying drawings in which

Figs. 1 and 3 represent solid delay lines embodying the invention,

Fig. 2 illustrates the beam splitting operation of Figs. 1 and 3,

Figs. 4, 6 and 7 show liquid delay lines embodying the invention.

Fig. 5 illustrates the beam splitting process in Figs. 4, 6 and 7, and

Fig. 8 illustrates a delay means in accordance with

2

the invention using partially absorbing output transducers.

Referring to Fig. 1, 1 represents a solid block of suitable acoustic wave transmitting material such as quartz. An input electro-acoustical transducer T_1 , which may be of the piezoelectric type and to which the electrical signal to be delayed is applied, is acoustically coupled to face 2 of block 1 and produces a beam 3 of acoustic energy which is directed toward and centered relative to the line of intersection 4 of faces 5 and 6. Beam 7 is formed by internal reflection from face 5 and beam 8 is formed by internal reflection from face 6, each beam having half the power of the original beam 3. For simplicity, single lines are used to represent the beams in Fig. 1, however, the beams actually have finite widths as shown in Fig. 2 which illustrates the beam splitting process in more detail. Beam 8 travels directly to output transducer T_{01} which is acoustically coupled to face 9, while beam 7, after being reflected from faces 10 and 9, is directed to output transducer T_{02} which is acoustically coupled to face 6. These transducers reconvert the acoustical energy back into an electrical signal of the same type as initially applied to T_1 . Since the path 3—8 is shorter than the path 3—7, the signal output of T_{02} is delayed relative to the input signal by an amount greater than the signal output of T_{01} .

Fig. 3 is a modification of Fig. 1 to provide three different delays. In this modification, acoustic beams are split on two occasions. Beam 3 is split into beams 8 and 7 as in Fig. 1. However, beam 7, instead of going directly to an output transducer, is split into beams 11 and 12 at the intersection of faces 13 and 14 of block 1'. Beam 11 is directed to transducer T_{02} and beam 12, after reflection from face 9, is directed to output transducer T_{03} . It is evident that the lengths of paths 3—8, 3—7—11 and 3—7—12 are all different and that the delays experienced by the output signals of T_{01} , T_{02} and T_{03} are different.

Fig. 4 illustrates the application of the invention to an acoustic delay line of the liquid type. In this figure, which is a horizontal section of the delay line, a container 15 holds a suitable liquid acoustic wave transmitting material 16 such as mercury. Input transducer T_1 and output transducers T_{01} and T_{02} are acoustically coupled to the mercury. The electrical signal to be delayed is applied to input transducer T_1 which produces a beam of acoustic energy 17 directed toward the intersection of reflecting surfaces 18 and 19. Reflection from surface 18 produces beam 20 and reflection from surface 19 produces beam 21, the splitting process being illustrated in more detail in Fig. 5. Beam 20 is directed to output transducer T_{01} and beam 21 to output transducer T_{02} . Since paths 17—20 and 17—21 have different lengths the output signals at T_{01} and T_{02} have different delays relative to the input signal at T_1 .

Fig. 6 shows a horizontal section of a liquid delay line employing the principles of Fig. 4 in which the container 15' is provided with means for splitting acoustic beams three times to provide four different delays of the input signal applied to T_1 . Beam 17 is split at surfaces 18—19 to form beam 20, directed toward output transducer T_{01} , and beam 21 which is split by surfaces 22—23 into beams 24 and 25. Beam 25 is directed to T_{02} , but beam 24 is split by surfaces 26 and 27 into beams 28 and 29 which are directed to T_{03} and T_{04} , respectively. It is seen that the four delay paths 17—20, 17—21—25, 17—21—24—28 and 17—21—24—29 are of progressively greater lengths, producing progressively greater delays of the signals at T_{01} , T_{02} , T_{03} and T_{04} relative to the input signal.

3

Fig. 7 is a modification of Fig. 4 using multiple reflections from the inner surfaces of the walls of container 15" to produce greater delays for a given physical size, than in Fig. 4. In this embodiment, acoustic beam 17, produced by input transducer T_1 , is split by intersecting reflecting surfaces 30—31 to produce beams 32 and 33. After three reflections from the inner wall surfaces beam 33 reaches output transducer T_{01} and after five such reflections beam 32 reaches output transducer T_{02} , the two paths being of different lengths and relatively long due to the multiple reflections.

Fig. 8 utilizes the principle of partial absorption of the incident acoustic wave by the output transducers to provide several delays in a single delay medium. In this figure, 1" represents a block of suitable acoustic wave transmitting material such as quartz. Input transducer T_1 , to which the electric signal to be delayed is applied, is acoustically coupled to face 34 and produces the beam of acoustic wave energy 35 which strikes output transducer T_{01} at an angle. The acoustic coupling between T_{01} and face 36, which may be controlled, for example, by etching face 36, is made such that half the energy in beam 35 is absorbed by T_{01} and the other half is reflected along beam 37 to T_{02} . There is also 50% acoustic coupling between T_{02} and face 38 so that half the energy in beam 37 is absorbed by T_{02} and the other half reflected to T_{03} . As in the preceding instances, the acoustic paths between T_1 and the output transducers T_{01} , T_{02} and T_{03} are of different lengths producing output signals having different delays relative to the input signal at T_1 . This principle may be applied equally well to liquid acoustic delay lines.

We claim:

1. An electrical signal delay means comprising a polyhedron of solid acoustic wave transmitting material bounded by internally reflecting plane surfaces all normal to a reference plane, an input electro-acoustical transducer acoustically coupled to one of said bounding surfaces for converting an input electrical signal into a beam of corresponding acoustic wave energy directed toward the line of intersection of two other of said bounding surfaces whereby said beam is split into two parts, a pair of output electro-acoustical transducers for converting

4

incident acoustic wave energy into a corresponding electrical signal, one of said output transducers being acoustically coupled to one of said bounding surfaces in position to receive the acoustic wave energy in one of said parts and the other of said output transducers being acoustically coupled to another of said bounding surfaces in position to receive at least a portion of the acoustic energy in the other of said parts, the paths over which the energies in said two parts travel to said output transducers being of different lengths.

2. An electrical signal delay means comprising a container holding an acoustic wave transmitting liquid, means providing in said container a pair of intersecting plane reflecting surfaces, said surfaces being in contact with said liquid and having an angular separation exceeding 180° , an input electro-acoustical transducer attached to said container and acoustically coupled to said liquid for converting an input electrical signal into a beam of corresponding acoustic wave energy directed toward the line of intersection of said surfaces whereby said beam is split into two parts, a pair of output electro-acoustical transducers for converting incident acoustic wave energy into a corresponding electrical signal, one of said output transducers being attached to said container and acoustically coupled to said liquid in position to receive at least a portion of the acoustic energy in the other of said parts, the paths over which the energies in said two parts travel to said output transducers being of different lengths.

References Cited in the file of this patent

UNITED STATES PATENTS

2,465,993	Beechlyn	Apr. 5, 1949
2,503,165	Meyer	Apr. 4, 1950
2,505,515	Arenberg	Apr. 25, 1950
2,612,814	Glasser	Oct. 7, 1952
2,664,547	Beveridge	Dec. 29, 1953
2,672,590	McSkimin	Mar. 16, 1954
2,845,710	Claret et al.	Aug. 5, 1958