Dec. 5, 1961 W. P. MASON 3,012,211

MICROWAVE ULTRASONIC DELAY LINE

Filed Jan. 27, 1959

FIG. 1

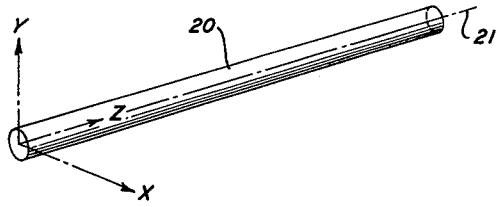



FIG. 2

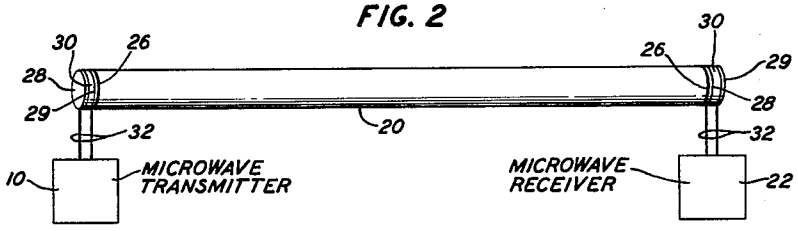



FIG. 3

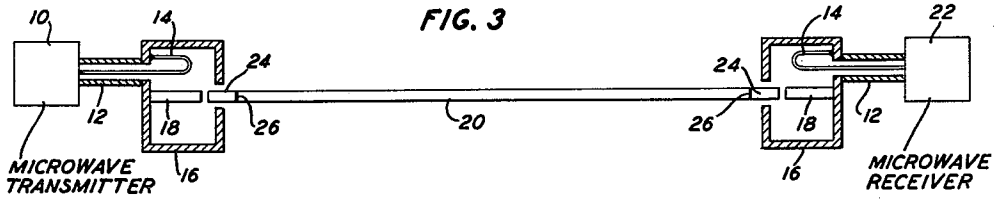
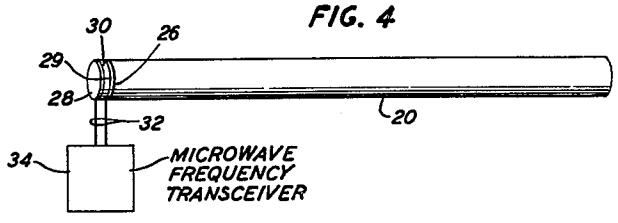



FIG. 4




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# MICROWAVE ULTRASONIC DELAY LINE

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5 Claims. (Cl. 333—30)

This invention relates to ultrasonic delay lines and to systems employing such lines. More particularly, it relates to ultrasonic delay lines for operation at microwave frequencies.

It is known that ultrasonic waves of microwave frequencies, i.e. of frequencies, for example, within the range of 500 megacycles to 4,000 megacycles per second, can be transmitted through a quartz rod and that delays of 100 microseconds or considerably more could be conveniently and economically realized by a delay line comprising such a quartz rod provided that the loss incurred in transmitting the ultrasonic waves through the quartz could be substantially reduced from the values which have been encountered in the past with devices of this character. By way of specific example, a loss of 64 decibels per centimeter at room temperature has been commonly associated with the use of quartz rod delay lines of the prior art at the upper end of the above-mentioned frequency range. Such a high loss makes the use of quartz delay lines at room temperature impracticable for most purposes. In general, the loss increases approximately as the square of the frequency.

In the application of H. E. Bommel and K. Dransfeld, Serial No. 784,218, filed December 31, 1958, and assigned to applicant's assignee, it is disclosed that specific cuts of quartz when held at very low temperature, for example, at 20 degrees Kelvin, or below, will have greatly reduced transmission loss to ultrasonic waves. However, it is expensive and inconvenient to maintain the delay lines at such low temperatures.

Accordingly, it is a principal object of the present invention to eliminate the necessity of maintaining the temperature of a quartz rod ultrasonic delay line far below the normal room temperature range and still avoid the excessive transmission losses heretofore incurred when using a quartz rod as a delay line to transmit ultrasonic, microwave frequency wave energy.

This object is accomplished in accordance with the present invention by cutting the delay line as a rod from a single crystal of quartz with the longitudinal axis of the rod parallel to the optic axis, usually referred to as the Z axis, of the quartz crystal, and a rod so cut is commonly referred to as a Z-cut rod. The transmission loss of such a rod to longitudinal mode, microwave frequency, ultrasonic wave energy is very small at normal room temperatures, for example, in the neighborhood of 0.5 decibel per centimeter at a frequency of 1,000 megacycles per second. Accordingly, cooling to a very low temperature as taught by Bommel and Dransfeld in their above-mentioned copending application is not required with Z-cut quartz delay lines. It is, however, necessary to employ separate transducing means at each end of the Z-cut rod since the Z-cut quartz rod does not possess piezoelectric properties.

The above and other objects, features and advantages of the invention will be more readily perceived from a perusal of the following detailed description of specific illustrative embodiments of the principles of the invention.

In the drawing:

FIG. 1 illustrates the orientation of a Z-cut quartz rod with respect to the crystallographic axes of the single crystal of quartz from which it is cut;



FIG. 2 illustrates in partially diagrammatic form a system employing a Z-cut quartz rod delay line;

FIG. 3 illustrates in partially diagrammatic form a second system employing a Z-cut quartz rod delay line; and

FIG. 4 illustrates in partially diagrammatic form a third system employing a Z-cut quartz rod delay line.

In more detail in FIG. 1, an elongated quartz rod **20** is represented which is cut from a single crystal of quartz with its longitudinal axis **21** parallel to the optic or Z axis of the quartz crystal as indicated by the arrows designated X, Y and Z representing the directions of the electrical, mechanical and optic crystallographic axes, respectively, of the single quartz crystal from which rod **20** has been cut. Such a rod is commonly referred to as a Z-cut rod.

In FIG. 2 a first system for employing the Z-cut rod **20** of FIG. 1 is shown in partially diagrammatic form. Piezoelectric transducing crystals **30** of cylindrical shape, equipped with conductive electrodes **28** and **29** on their oppositely disposed circular faces, are cemented to the left and right ends, respectively, of rod **30** by a very thin layer or bond of indium **26**, as shown. Indium bonds are preferable since a very thin layer of indium will provide a strong bond and introduce appreciably less loss or dissipation than others of the numerous and varied bonds well known and extensively used by those skilled in the art. These transducers may be, for example, of X-cut quartz, which will generate a longitudinal mode in the Z-cut rod. They should be made as thin as possible, in order to obtain as high a fundamental frequency as possible, and may be operated at a high harmonic to obtain the very high frequencies specified in the application. Transducers as thin as five thousandths of an inch have been made and operated satisfactorily.

The electrodes **28**, **29** of transducer **30** on the left are connected by the associated leads **32** to a source of microwave frequency electrical wave energy as represented, by way of specific example, by the microwave frequency transmitter **10**. The electrodes **28**, **29** of transducer **30** on the right are similarly connected by the associated leads **32** to a utilization circuit for microwave frequency electrical wave energy as represented by way of specific example by the microwave frequency receiver **22**. Accordingly, the application of microwave frequency electrical wave energy to the electrodes **28**, **29** of transducer **30** at the left by transmitter **10** results in the generation of longitudinally directed ultrasonic waves of corresponding frequency which are launched in rod **20** and travel to the opposite or right end of the rod where the transducer **30** at the right end converts the ultrasonic waves back into electrical waves which are then carried by leads **32** associated with this transducer to the utilization device represented by microwave frequency receiver **22**.

In FIG. 3, a system similar to that of FIG. 2 is represented in partially diagrammatic form. The system of FIG. 3 differs from that of FIG. 2 in that the transducers **30** of FIG. 2 are replaced in FIG. 3 by short sections of X-cut quartz crystal rod **24** coupled through resonant cavities **16**, coupling loops **14** and coaxial lines **12** to transmitter **10** at the left end and to receiver **22** at the right end, respectively, the over-all system being similar to that described in detail in the above-mentioned copending application of Bommel and Dransfeld except that Z-cut quartz rod **20** is inserted between the X-cut ends **24** in the present application rather than having the whole rod of X-cut quartz as suggested in the copending application.

Tuning stubs **18** are provided in each of the cavities **16** to concentrate the electrical lines of force about the ends of members **24** protruding into the cavities. The

cavities **16** are preferably tuned to be resonant at the mid-frequency of the energy to be transmitted along rod **20** from transmitter **10** to receiver **22**.

The short X-cut members **24** are cut from a single crystal of quartz with their respective axes of rotation, i.e. their longitudinal axes, parallel to the X or electrical crystallographic axis of the quartz crystal from which they are cut. Referring to FIG. 1, it is apparent from the arrows X, Y and Z shown in that figure, representing the crystallographic axes of a quartz crystal, that members **24** should be cut from the quartz crystal with their longitudinal axes at right angles with respect to the direction of the longitudinal axis of rod **20** with respect to the crystal axes and also with respect to the mechanical crystallographic axis Y of the single crystal from which they are cut. Members **24** are preferably also bonded by thin layers of indium **26** to the ends of the Z-cut quartz rod **20** as indicated in FIG. 3.

The system of FIG. 4 differs from that of FIG. 2 in that a single piece of apparatus, namely transceiver **34**, is employed both as the source of microwave energy to be transmitted along the Z-cut quartz rod **20** and as the utilization circuit to receive the energy which has been transmitted along rod **20**, reflected from its right end and returned to its left end. Obviously, only a single transducer **30** is required for this system. Such a system is commonly employed to obtain timing pulses, where one or more echoes (that is, reflections from the far or right end of rod **20**) are recovered at the near or left end and are obviously delayed with respect to an input or initial pulse by an integral multiple of the time required for a pulse to travel to the far end of the rod and return.

Systems of the types described hereinabove employing Z-cut quartz delay lines are obviously useful in radar and other systems for various timing functions or for "memory units" for information storage purposes.

Numerous and varied other arrangements and modifications of the systems disclosed hereinabove employing the principles of the present invention can be readily devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In combination, an elongated quartz rod cut from a single crystal of quartz, the longitudinal axis of the rod being parallel to the optic axis of the quartz crystal from which it is cut, and a pair of electromechanical transducers adapted to convert microwave frequency electrical wave energy into ultrasonic wave energy, and vice versa, one of said transducers being bonded to each end of the quartz rod, respectively.



2. The combination of claim 1 in which the transducers are piezoelectric crystals.

3. The combination of claim 1 in which the transducers each comprise a short member cut from a single crystal of quartz with its longitudinal axis parallel to the electrical crystallographic axis of the crystal, the member protruding into a resonant cavity tuned to the median frequency of the frequency range to be used, the other end of the member being bonded to an end of the elongated quartz rod.

4. A system comprising a source of microwave frequency electrical wave energy, a utilization circuit for the microwave frequency electrical wave energy, a quartz rod cut from a single crystal of quartz with its longitudinal axis parallel to the optic axis of the crystal from which it was cut, a pair of electromechanical transducers adapted to convert microwave frequency electrical wave energy into ultrasonic acoustic wave energy and vice versa, one of the transducers interconnecting one end of the quartz rod with the source, the other interconnecting the other end of the quartz rod with the utilization circuit.

5. A system comprising a source of microwave frequency electrical wave energy, a utilization circuit for microwave frequency electrical wave energy, a quartz rod cut from a single crystal of quartz with its longitudinal axis parallel to the optic axis of the crystal, and electromechanical transducing means for converting microwave frequency electrical wave energy into microwave frequency ultrasonic wave energy and vice versa, the last stated means interconnecting the rod with the source and with the utilization circuit.

References Cited in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 2,309,467 | Mason | Jan. 26, 1943 |
| 2,712,638 | Arenburg | July 5, 1955 |
| 2,773,996 | Slater | Dec. 11, 1956 |
| 2,877,431 | McSkimin | Mar. 10, 1959 |
| 2,883,660 | Arenburg | Apr. 21, 1959 |
| 2,894,222 | Goldan | July 7, 1959 |

OTHER REFERENCES

Arenberg: "The Journal of The Acoustical Society of America," vol. 20, No. 1, January 1948, pages 1–26.