

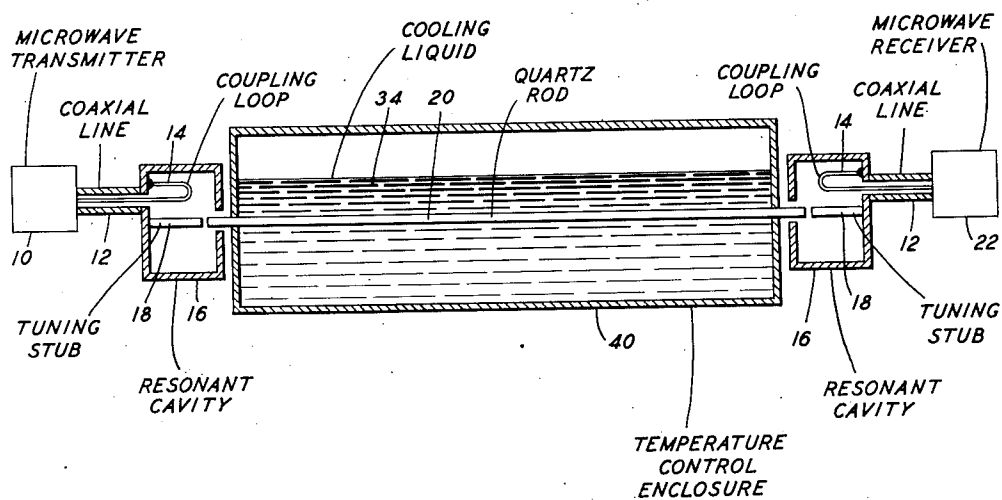
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MICROWAVE ULTRASONIC DELAY LINE

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MICROWAVE ULTRASONIC DELAY LINE

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4 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 and to equipment for generating microwave frequency ultrasonic energy.

It is known in the art that ultrasonic waves of microwave frequencies, i.e., of frequencies, for example, within the range of 1,000 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 transmission loss ranging from 4 to 64 decibels per centimeter at room temperature is commonly encountered in quartz at frequencies within the above range, the loss increasing approximately as the square of the frequency.

Accordingly, a principal object of the present invention is to reduce the transmission loss incurred in transmitting microwave frequency ultrasonic energy through quartz delay lines.

A further troublesome problem has been that of generating microwave frequency ultrasonic waves of the above-mentioned range in quartz delay lines.

A further object is to provide novel means for generating microwave frequency ultrasonic wave energy in quartz delay lines.

In accordance with the present invention, the temperature of the quartz delay line is lowered to a very low temperature. For the majority of cases, a temperature of 20 degrees Kelvin or below is required, as will be discussed in more detail below but some improvement is noted at even higher temperatures. Such temperatures are conveniently realized by immersing the quartz rod in liquid hydrogen or helium. Microwave frequency ultrasonic energy is obtained by applying electrical microwaves to a resonant cavity within which the quartz rod protrudes.

Other and further objects, features and advantages of the invention will become apparent during the course of the following detailed description of a specific illustrative arrangement embodying the principles of the invention.

The sole FIGURE of the accompanying drawing illustrates in diagrammatic form one specific example of an arrangement for practicing the principles of the invention.

In more detail, in the drawing a microwave frequency transmitter 10 is connected by a short length of coaxial line 12 to coupling loop 14 of the adjacent metallic resonant cavity 16. The left end of an elongated quartz rod 20 protrudes a short distance into the cavity 16, as shown, and a metallic tuning stub 18 attached to the left wall of the cavity 16 is preferably positioned, as shown, so as to cause a concentration of the lines of electric force, generated in the cavity 16, in the vicinity of the end of the quartz rod 20. The axis of tuning stub 18 is situated along the extension of the longitudinal axis of the quartz rod 20. Rod 20 is cut from a single crystal of quartz and by way of specific example may have its longitudinal axis parallel to the "X" crystallographic axis of

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the crystal if it is to propagate longitudinal waves. Alternatively, if it is desired to propagate transverse waves, the rod may be cut from the crystal in accordance with the well known AC or BC cuts. For exceptionally long delay lines, each end of rod 20 may comprise a quartz member cut from a single crystal at the appropriate orientation and the more central portion of the rod may be of polycrystalline quartz with its ends bonded to the two single crystal members, respectively. Stub 18 may be spaced a short distance from the end of rod 20 as shown or, alternatively, it may be in physical contact with it. Likewise, the opening in the cavity 16 through which rod 20 protrudes may be slightly larger than rod 20 as shown or, alternatively, it may provide a close sliding fit with rod 20. Cavity 16 is resonant at the frequency supplied by transmitter 10 and serves to generate ultrasonic waves in rod 20 of the same frequency as that of the electrical energy. Applicants have discovered that this very convenient method of generating ultrasonic waves is applicable in any situation in which the surface of the quartz is subjected to an intense microwave frequency electric field.

At the right end of rod 20 a second resonant cavity 16 may be coupled to the right end of rod 20 and will respond to the ultrasonic waves on rod 20 by generating microwave electrical energy of corresponding frequency. The cavity 16 is electrically connected through a second coupling loop 14 and short section of coaxial line 12 to microwave receiver 22.

An enclosure 40 surrounds the quartz rod 20, except for the small portions extending into the cavity 16 at each end of the rod. Enclosure 40 contains an appropriate cooling liquid 34, selected to establish the desired temperature of rod 20 at which its transmission loss to the ultrasonic waves being transmitted is very small. Rod 20 is preferably completely immersed in the liquid 34.

Three widely used cooling liquids for establishing very low temperatures are liquid nitrogen, liquid hydrogen and liquid helium. Temperatures readily maintained by these three liquids are, respectively, 77 degrees Kelvin, 20 degrees Kelvin and 4 degrees Kelvin.

Over the frequency range of 1,000 to 4,000 megacycles per second, the transmission loss of a quartz rod can be reduced to approximately one-tenth of a decibel per centimeter by lowering its temperature to 20 degrees Kelvin. Accordingly, for the majority of cases, the cooling liquid 34 may be liquid hydrogen. In some cases, particularly when frequencies in the upper half of the above-mentioned range are to be used, it is advisable to employ liquid helium as the cooling liquid 34.

Delay lines as described above are useful, for example, in various radar circuits. Numerous and varied other arrangements and modifications within the spirit and scope of the principles of the invention will readily occur to those skilled in the art.

What is claimed is:

1. A source of kilomegacycle microwave frequency electrical energy, a first electrically resonant cavity coupled to the source and having a resonant frequency equal to the frequency of the source, an elongated rod cut as a unitary member from a single crystal of quartz, one end of the quartz rod extending into the resonant cavity to a point of substantially maximum intensity of the electric field established in the cavity to directly generate kilomegacycle microwave frequency ultrasonic energy in the rod having a frequency equal to the frequency of the source, a second resonant cavity identical to the first cavity coupled in like manner to the other end of the rod to directly convert the ultrasonic energy transmitted along the rod to electric energy of the same frequency in the cavity, a utilization circuit coupled to the second resonant

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cavity, and means for reducing the temperature of the rod to a temperature not exceeding 20 degrees Kelvin whereby the transmission loss of the ultrasonic energy passing along the rod is reduced to a very small fractional part of its value at temperatures higher than 70 degrees Kelvin.

2. The arrangement of claim 1 in which the rod is cut from a single crystal of quartz with its longitudinal axis parallel to the electrical or X crystallographic axis of the single crystal from which it is cut.

3. The arrangement of claim 1 in which the rod is cut from a single crystal of quartz with its longitudinal axis aligned with the crystallographic axis of the single crystal from which it is cut as required for one of the cuts of the class which consists of AC and BC cuts.

4. In combination, a source of kilomegacycle microwave frequency electrical energy, an elongated rod cut as a unitary member from a single crystal of quartz, means for coupling one end of the rod to the source and for generating ultrasonic energy of like frequency in the rod, a utilization circuit, means coupling the other end of the rod to the utilization circuit, and means for lower-

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ing the temperature of the rod to a temperature not exceeding 20 degrees Kelvin at which the transmission loss in the rod to the ultrasonic energy is reduced to a very small fractional part of its value at temperatures higher than 70 degrees Kelvin.

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