Feb. 6, 1962 R. BECHMANN 3,020,424

PIEZOELECTRIC CRYSTAL

Filed May 8, 1958

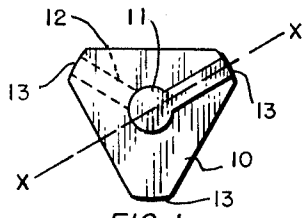


FIG. 1

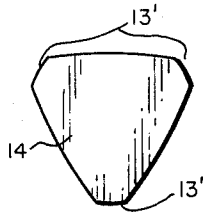


FIG. 2

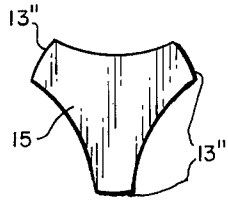


FIG. 3

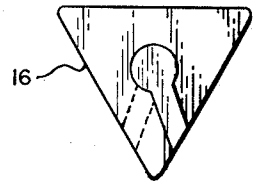


FIG. 4

FIG. 5

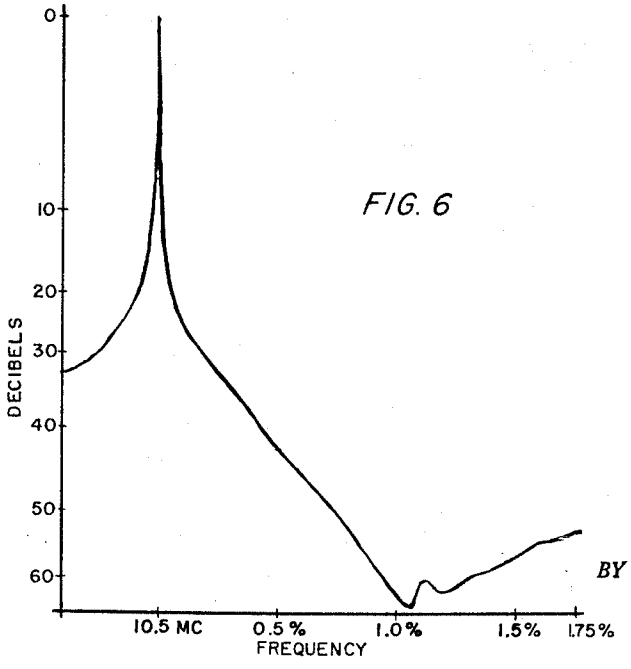


FIG. 6

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PIEZOELECTRIC CRYSTAL

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1 Claim. (Cl. 310—9.5)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment of any royalty thereon.

This invention relates to the piezoelectric crystals which are operative at very high frequencies and possess the ability to overcome tendencies to oscillate at near harmonic frequencies.

The invention provides a solution to efficient operation of quartz crystals of the AT and BT types when used in applications demanding very high oscillation frequency in a single mode and the ability to suppress other modes. Crystals having the qualities to meet the above demands, in effective degree, have not heretofore been available. Piezoelectric elements designed according to the principles of the invention exhibit marked improvement over existing crystal types.

The crystals referred to herein are those which are vibrated in thickness shear mode. Such crystals have been made in which spurious modes were suppressed to a limited degree. In developing these early techniques it was found that rectangular crystal plates failed to respond satisfactorily to rejection of spurious modes. Improved results were obtained with peripherally round plates. By suitable bevelling of the edges of the plates a degree of spurious mode rejection could be established, but a great deal of improvement was desired. The most satisfactory crystals then used were round parallel faced plates having a diameter to thickness ratio less than 20. Crystals having slightly higher ratios showed some response to edge bevelling. However, in crystals having ratios 40 to 100 no satisfactory solution to controlling spurious modes was known. This was unfortunate because in the future more and more use will be made of the higher frequencies such as 10 to 30 megacycles.

The matter of physical size of these high frequency crystals has presented difficulties in their efficient design. If they are too small the application of electrodes becomes more and more difficult. For example, a 10 mc. crystal vibrating in the fundamental mode has a diameter of 10 millimeters and a thickness of .166 millimeter. In such a crystal the practical minimum size for an electrode is 4 millimeters. Smaller electrodes are not desirable. The diameter thickness ratio in this crystal becomes about 60, which is its practical limit. A large diameter therefore cannot be used. Crystals for higher frequencies become very small and very thin. It was also found that existing techniques were ineffective in controlling spurious modes in such thin crystal plates.

It is a primary object of the invention to provide a piezoelectric crystal which is capable of suppressing unwanted modes of oscillation therein.

A further object of the invention is to provide a crystal which is particularly effective in discriminating against spurious modes at high frequencies such as at 10 mc. or more.

A further object of the invention is to provide a high frequency crystal having suitable discriminating characteristics and also providing adequate facility for applying electrodes thereto and for mounting the crystal.

A further object of the invention is to provide a crystal having a general conformation invoking special peripheral

contours adaptable to provide optimum discrimination against spurious modes.

Other objects and features of the invention will more fully appear from the following description and will be particularly pointed out in the claim.

To provide a better understanding of the invention specific forms thereof will be described and illustrated in the accompanying drawings wherein:

FIGURE 1 is a general view of a crystal prepared in accordance with the invention.

FIGURES 2, 3 and 4 are modified forms of the crystal plate shown in FIGURE 1.

FIGURES 5 and 6 are respectively graphical representations of performance of crystals constructed according to best known techniques before the present invention and the performance of crystals made according to the invention.

The techniques of the present invention are directed to the control of spurious modes by designing the peripheral shape of the plates. Following the principles of the invention certain shapes have been developed which demonstrate the true capabilities of the invention. These shapes depart deliberately from rectangular and round configurations. As shown in the drawings the forms are generally polygonal but non rectangular. A very satisfactory conformation has been found to be the triangle.

Referring to the drawings, FIGURE 1 illustrates a straight sided triangular crystal **10** wherein its sides are formed by removing segments of a round crystal. Its apexes **13** are designed to receive the electrodes **11** and **12**. Its faces are ground and finished parallel or may be given a slightly convex curvature.

The crystal **10** is designed for high frequency operation, its fundamental or overtone operating frequency being in the order of 10 megacycles or higher. This crystal has a diameter to thickness ratio of about 60 and functions in thickness shear mode. A suitable mounting is provided by soldered or spring clip connections to its electrodes.

The electrodes **11** and **12** are applied by plating on the respective faces of the crystal and are so disposed that they do not lie parallel to a diametrical line. A suitable arrangement is shown in FIGURE 1 wherein the electrodes are so placed that their inner ends are at the geometrical center of the crystal and extend radially outward to the outer edge of adjacent apex portions **13** of the crystal. Suitable diameters for high frequency crystals are 13 to 6 millimeters, while the useful electrode diameters are 4 to 2 millimeters.

Particular variations of the crystal shown in FIGURE 1 are those shown in FIGURES 2, 3 and 4. In FIGURE 2, the sides **14** of the triangle are slightly convexed and in FIGURE 3 the sides **15** are concaved. While the straight sided shape is preferred, the other shapes are found to be effective in suppressing reflections causing standing waves in the plane of the crystal. The segments removed from the round plate may be unsymmetric and of different size. The shape shown in FIGURE 4 has been found to be highly efficient. In this construction the crystal is a true equilateral triangle having straight sides **16**.

Actual tests show a great improvement in the performance of a crystal embodying the invention especially with respect to discrimination against unwanted frequencies. FIGURE 5 of the drawings illustrates graphically the attenuation versus frequency of a circular crystal having a fundamental frequency of 10 megacycles. This crystal was prepared according to methods existing before the present invention for avoiding spurious harmonics of vibration in the thickness shear mode. The curve in this case shows undesirable response in modes relatively close to the fundamental peak response.

FIGURE 6 shows the response characteristic of a crystal having the same fundamental as that used in the test of FIGURE 5, but having the shape of the crystal shown in FIGURE 4. This test shows that the crystal in FIGURE 4 substantially reduces spurious modes. In this latter example the first spurious mode from the wanted mode is about 1.5%, while the amplitude of the first spurious mode is down 60 decibels. The other forms of the crystals shown exhibit similar favorable characteristics.

What is claimed is:

A thickness shear piezoelectric crystal element comprising a quartz plate having a peripheral contour in the shape of an equilateral triangle, said contour being derived from and having its apices extending substantially to the periphery of a disc shaped quartz crystal having a diameter to thickness ratio of about 60, said thickness and said equilateral triangle shape of said crystal being such as to restrict the crystal to oscillation in thickness shear mode at not less than 10 megacycles, and said oscillation occurring with a sharp peak response at its fundamental frequency and nearly complete rejection of spurious harmonics occurring close to the fundamental frequency.

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