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PIEZOELECTRIC CRYSTAL

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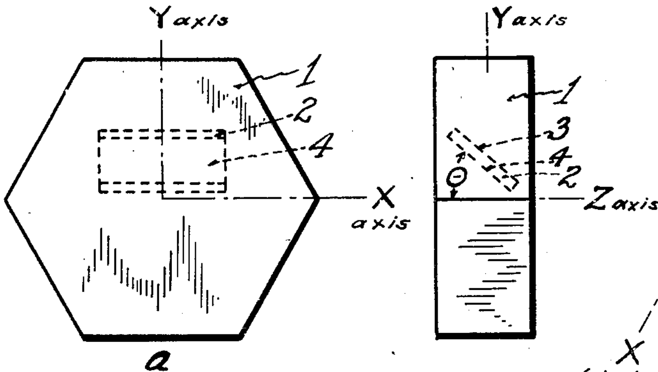

Fig. 1

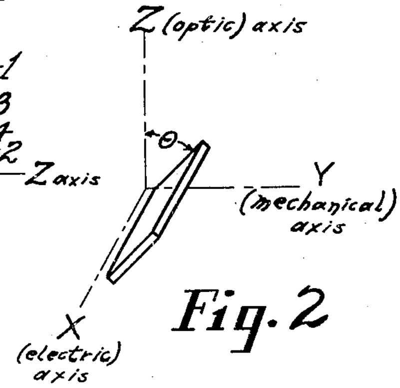

Fig. 2

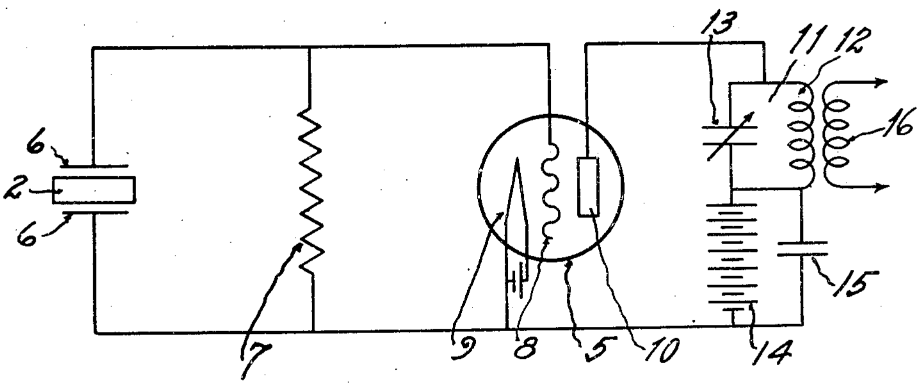

Fig. 3

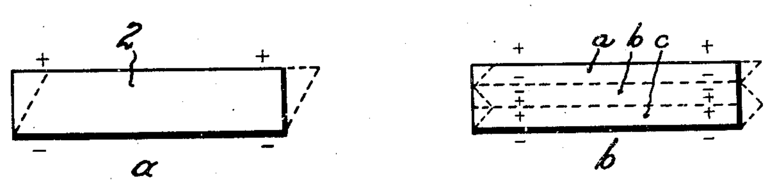

Fig. 4

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2,157,808

PIEZOELECTRIC CRYSTAL

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3 Claims. (Cl. 171—327)

This invention relates to piezo-electric crystals and apparatus for employing piezo-electric crystals, generally. More particularly this invention relates to piezo-electric crystals and apparatus for employing piezo-electric crystals adapted for generating ultra-high frequency electric oscillations.

An object of this invention is to provide a piezo-electric crystal adapted for harmonic operation.

Another object of this invention is to provide a piezo-electric crystal adapted to oscillate efficiently at frequencies which are materially higher than its fundamental frequency.

A further object of this invention is to provide a piezo-electric crystal adapted to sustain oscillations which bear an harmonic relation to its fundamental frequency.

Still a further object of this invention is to provide a piezo-electric crystal of quartz ground to a thickness such that the fundamental frequency of the crystal is in the neighborhood of 4 megacycles and operating the crystal on a harmonic of the fundamental frequency for stabilizing the frequency of electric oscillations of said harmonic frequency.

Still another object of this invention is to provide a piezo-electric crystal oscillator adapted to stabilize the frequencies of oscillations of ultra-high frequencies.

Still another object of this invention is to provide a piezo-electric crystal cut and ground in such a manner that the crystal can be made to oscillate at frequencies which bear an harmonic relation to the fundamental thickness vibration frequency.

Still another object of this invention is to provide a crystal oscillation generator adapted to oscillate readily and efficiently at any one of a series of progressively increasing high frequencies.

Other and further objects of this invention will be apparent from the following specification and claims.

In accordance with this invention I provide means employing an element exhibiting piezo-electric properties for generating and/or stabilizing high frequency oscillations. The piezo-electric crystal is cut and ground in such a manner that it readily produces and stabilizes high frequency oscillations of extremely high frequencies. This is accomplished by selecting a crystal, the fundamental frequency of which bears an harmonic relationship to the frequency of the ultra-high frequency oscillations which it is desired to produce and/or stabilize.

My invention greatly simplifies piezo-electric quartz crystal controlled oscillation generation inasmuch as it eliminates the necessity of employing frequency doublers and frequency multipliers. This is a material advantage since losses in frequency doublers and multipliers are enormous when working with oscillations having frequencies higher than 30.0 megacycles. My invention readily produces oscillations higher than 30.0 megacycles which are frequency stabilized, without requiring the use of any frequency doublers and multipliers.

I accomplish this by cutting or grinding the crystal in such a manner that its vibrations on the harmonic frequencies are stronger. I prefer to employ a transverse or shear vibration, and in so doing greatly increase the strength of the vibrations corresponding to the odd harmonics. Vibrations other than the transverse or shear type may be employed.

By harmonics or harmonic frequencies I mean various frequencies called overtones which are approximately integral multiples of the fundamental frequency. Thus, odd harmonics would be approximately odd multiples, of the fundamental frequency. By selecting odd harmonics such as the third, fifth, seventh, ninth, eleventh, and so on, of, for example, a crystal that will oscillate on a fundamental frequency of 7.5 megacycles, vibrations of ultra-high frequencies such as 22.5 megacycles corresponding to the third harmonic, 37.5 megacycles corresponding to the fifth harmonic, 52.5 megacycles corresponding to the seventh harmonic, 67.5 megacycles corresponding to the ninth harmonic, may be obtained directly from the crystal oscillator. The crystal will be 3, 5, 7, or 9 times, etc., thicker than if it were operating on its fundamental at the same frequency.

In this manner the crystal vibrating on an harmonic can be used as the primary source of oscillations when employed in a vacuum tube circuit, and will not necessarily be simply a stabilizing device in a self oscillatory circuit.

Another feature of this invention is that the crystal or piezo-electric body also may be operated on its harmonics when used as a resonator producing some reaction on an associate network, or it may be used in filter circuits.

A further advantage of this invention is that piezo-electric plates or elements may be ground to a thickness sufficient to withstand normal use without breakage. Electrical oscillations as high as those produced by piezo-electric elements of my invention could not be produced with piezo-electric elements of conventional cuts because the piezo-electric elements would have to be ground too thin and fragile, and would be impractical even if the quartz could be ground to the required dimension.

Other features and advantages of this invention will be apparent from the following specification and the accompanying drawing in which, briefly, Figure 1 illustrates the manner in which the crystal of my invention is cut from the quartz hexahedron; Figure 2 illustrates the orientation of a crystal with respect to the various crystallographic axes; Figure 3 illustrates an embodiment of a circuit arrangement in which the crystal of my invention may vibrate to produce oscillations and Fig. 4 illustrates enlarged views of the shear mode of vibration in a crystal element.

Referring to Fig. 1 of the drawing in detail, reference numeral 1 designates a section of a quartz hexahedron from which a plate or slab 2, adapted to be used as a piezo-electric crystal, is cut. The position of the plate 2 in the quartz hexahedronal crystal is shown in Fig. 1*a*, with respect to the x or electric axis and the y or mechanical axis. Fig 1*b* shows the angle at which the crystal plate is cut with respect to the z or optic axis. In Fig. 1*a* the quartz hexahedron is shown with the optic or z axis at right angles to the x and y axes which are illustrated in the same plane. Fig. 1*b*, however, shows the y and z axes in the same plane and the x axis at right angles to that plane. The plate 2 is cut from the crystal 1 in the manner shown, with the principal surfaces 3 and 4 of the plate, cut at an angle Ω with respect to the optic or z axis. The principal surfaces 3 and 4 are cut substantially parallel to the electric or x axis.

The values of the angle Θ may vary over rather wide limits, however, for best operation on harmonic frequencies, I have found that the plate should be cut at angles of plus 30 degrees or minus 19 degrees. For example, a crystal which would oscillate at 15 megacycles would be approximately .013″ thick for the 30° cut and approximately .018″ thick for the 19° cut. These thicknesses give strong, practical crystal plates satisfactory for use in electrical circuits.

The minus 19 degree angle produces a plate having a high frequency thickness coefficient, and the plus 30 degree angle produces a crystal having a low frequency-thickness coefficient.

There are two kinds of quartz, namely, right-handed and left-handed. In the case of right-handed quartz, the convention is adopted that a positive angle is a clockwise rotation of the principal axis (optic axis) when the electrically positive face as determined by a squeeze, is up. For left-handed quartz, a positive angle is a counter-clockwise rotation of the principal axis when the electrically positive face is up.

Angles other than those given in the foregoing paragraph may be used, however, if the angle Θ departs from the angles given by more than plus or minus 10 degrees, the operation of the crystal plate as an harmonic oscillator becomes unsatisfactory, apparently due to the lower activity of the crystal plate as an oscillator and also because of the higher coupling coefficient in the crystal to other vibrations.

The orientation of the crystal plate 2 with respect to the crystallographic axes x, y and z is illustrated in Fig. 2, wherein the substantially parallel relation of the sides 3 and 4 to the x axis, and an angle Θ between these sides and the z axis is shown.

One of the possible circuit arrangements illustrated in Fig. 3 shows the crystal plate 2 connected to control the frequency of an electric discharge device oscillation generator. The contact members 6 associated with the crystal plate 2 are of brass, bronze, copper, and like materials and are connected across the grid resistor 7 which is connected to the grid electrode 8 and cathode 9 of the tube 5. The anode 10 is connected to the oscillatory circuit 11 which includes an inductance unit 12 and a variable condenser 13. A source of anode current supply 14, shunted by the by-pass condenser 15, is connected to the oscillatory circuit 11 and the cathode 9.

The operation of the circuit illustrated in Fig. 3 is as follows: The condenser 13 is adjusted to tune the oscillatory circuit 11 to an harmonic frequency of the crystal plate 2, corresponding to the frequency of electrical oscillations that it is desired to produce. The crystal plate 2 impresses electric charges in the form of oscillations on the grid 8 of the tube 5 corresponding to the frequency to which the circuit 11 is tuned. These oscillations may be of a frequency much higher than the fundamental frequency of the crystal, as brought out in the preceding paragraphs herein, and yet electrical oscillations of ultra-high frequencies, derived from the oscillation generator and impressed upon the inductance 16, are of sufficient power and potential to be themselves suitable for driving an amplifier.

Fig. 4 illustrates the crystal plate of my invention vibrating at its fundamental frequency in shear or transverse vibration. The distribution of the positive and negative electrical charges on the crystal plate, is shown for a particular instant. This same crystal plate, vibrating at the third harmonic, is illustrated in Fig. 4*b*. The frequency of the oscillations derived from the crystal, vibrating as illustrated in Fig. 4*b* is three times the frequency derived from the crystal plate, vibrating as illustrated in Fig. 4*a*. The crystal in Fig. 4*b* may be considered as divided into three imaginary crystal plates *a*, *b* and *c* as defined by the dotted lines. The electrical charges on these imaginary crystal plates are designated, for a given instant by the plus and minus signs and it is seen that the polarity of the imaginary plate *b* is the reverse of that of the plates *a* and *c*, making the polarity on the surfaces of the crystal at a given instant, of opposite sign; a condition necessary for sustaining oscillations and a condition which always exists when operating the crystal at the odd harmonics.

By defining the angle Θ of the electrode faces of my crystal element or plate as substantially -19 degrees or substantially $+30$ degrees with respect to the z axis of the crystalline body, in the claims forming a part hereof, it is intended that this angle Θ may vary within limits set forth in preceding parts of this specification.

It will be observed that I have described an embodiment of my invention in detail however, I do not desire to limit this invention to the exact details set forth except insofar as those details are defined by the following claims.

What I claim and desire to secure by Letters Patent of the United States is as follows:

1. A piezo-electric crystal cut from a crystalline body and adapted for operation in a shear mode at an odd harmonic, said odd harmonic being a high or ultra high frequency, said crystal

being so cut that its electrode faces are substantially parallel to an x axis of the crystalline body and make an angle of substantially −19 degrees with the z axis of the crystalline body.

2. A method of operating a crystal at an odd harmonic in a shear mode which comprises so cutting the crystal that its electrode faces are parallel to the x axis and make an angle of substantially −19 degrees with the z axis and applying a field of a frequency corresponding to the desired shear mode harmonic.

3. A piezo-electric crystal cut from a crystalline body adapted for operation in a shear mode at an odd harmonic said odd harmonic being a high or ultra high frequency, said crystal being so cut that its electrode faces are substantially parallel to an x axis of the crystalline body and make an angle of substantially −19 degrees with the z axis of the crystalline body, said angle being such as will produce a low coupling coefficient in the crystal to other mode vibrations.

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