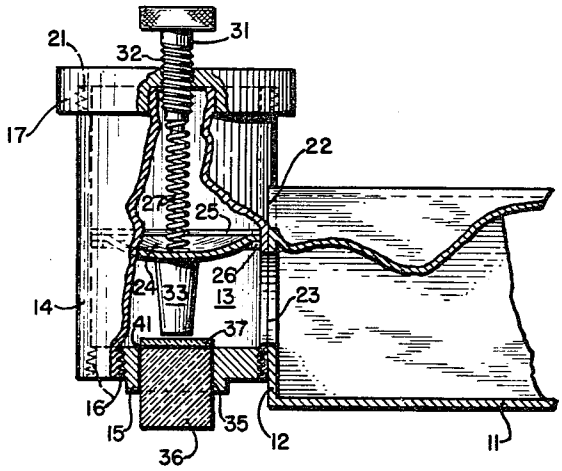
Dec. 11, 1956 J. C. SLATER 2,773,996

TRANSDUCER FOR PRODUCING SOUND AT MICROWAVE FREQUENCIES

Filed Sept. 13, 1946



INVENTOR
JOHN CLARKE SLATER

BY

ATTORNEY

United States Patent Office 2,773,996 Patented Dec. 11, 1956

2,773,996

TRANSDUCER FOR PRODUCING SOUND AT MICROWAVE FREQUENCIES

John Clarke Slater, Cambridge, Mass., assignor, by mesne assignments, to the United States of America as represented by the Secretary of the Navy

Application September 13, 1946, Serial No. 696,929

5 Claims. (Cl. 310—8.1)

This invention relates in general to electroacoustical systems, and more particularly to electromechanical transducers capable of the generation or conversion of supersonic (compressional) waves of ultra high frequency.

Supersonic signals at ultra high frequencies are of considerable value in the study of the structure of fluids, solids, colloidal suspensions and the like. Such signals are also of assistance in obtaining information concerning electrical problems involving crystal detectors and delay lines; and may be applied to study various biological effects.

The present invention contemplates and has as a primary object the provision of an electromechanical transducer operable at supersonic frequencies over a wide spectrum, including frequencies of the order of 3000 megacycles per second.

Another object of this invention is to provide a transducer in the form of a crystal or like piezoelectric element adapted for inclusion in high frequency electrical systems.

A further object of this invention is to provide a transducer, including a high frequency crystal operative within a resonant cavity.

A still further object of the present invention is to provide means for operating a high frequency crystal at a comparatively high harmonic of its fundamental frequency.

Another object of this invention is to provide a transducer readily adapted to supersonic experimentation.

These and other objects of the present invention will become apparent from the following specification when taken in connection with the accompanying drawing, the figure of which illustrates a preferred embodiment of an ultra high frequency transducer.

With reference now to the drawing there is illustrated an electrical system which comprises essentially a tunable resonant cavity and a transmission line coupled thereto. In the embodiment shown, the transmission line is a rectangular waveguide **11** having a terminating metallic plate **12**. It will be understood that the particular type transmission line utilized is a function of the frequencies involved and need not be limited to the waveguide as shown. At frequencies of the order of 3000 megacycles per second a rectangular guide is well suited.

A tunable resonant cavity **13** is formed within a conductive cylindrical structure **14**. At its lower end cylinder **14** is closed by a conductive wall **15**, which is removably attached by cooperating threads **16** on both cylinder and wall. This removable arrangement permits inspection and adjustment of the oscillating system to be described below.

At its upper end the cylinder **14** is closed by a cap **17** having internal threads **21** for engagement with corresponding threads on the cylinder **14**. A flat surface **22** is machined into the outer surface of cylinder **14** and is adapted to receive the end plate **12** of waveguide **11**.

The cylinder **14** and the waveguide **11** are secured along surface **22** by soldering or the like, and similar aligned openings **23** are provided in the joined surfaces. Openings **23** electrically couple resonant cavity **13** and transmission waveguide **11**.

Positioned within cylinder **14** is a flexible, saucer-shaped diaphragm **24** which forms the upper electrical boundary surface of resonant cavity **13**, and which is cricumferentially secured between a pair of cooperating circular flanges **25** and **26**. The flanges **25** and **26** are in turn fixed to the inner surface of cylinder **14**.

For tuning purposes, diaphragm **24** is engaged by a compression spring **27** which is fitted to the end of a knurled head bolt **31**. The threads **32** of bolt **31** pass through a correspondingly threaded opening in the center of cap **17**.

A conductive post **33** is centrally attached to the under surface of diaphragm **24**, and extends into the cavity **13**. The axial displacement of diaphragm **24** and post **33** may evidently be controlled by rotation of bolt **31**.

A central opening **35** is provided in the cavity wall **15**. A cylindrical supporting block **36** of quartz or similar substance is suitably secured within opening **35** such that the upper circular surface thereof is coplanar with the upper surface of wall **15**. A piezoelectric element, such as disc-shaped quartz crystal **37** is employed as the supersonic transducer. This crystal is preferably polished and silvered, or otherwise metalized, over its lower surface. The upper surface of quartz block **36** is correspondingly silvered and both crystal and block are joined as shown in the drawing by soldering together these metalized surfaces. A low melting point solder, such as Wood's metal is preferably employed, forming a conductive metallic film **41** at the junction, which film is in electrical contact with the surface of wall **15** along its circular edge.

The conductive film **41** functions, as a mechanical bond, and in addition, as a continuation of the metallic surface of the cavity wall **15**, and permits the substantially unimpeded transfer of mechanical vibrations therethrough.

The upper surface of crystal **37** is separated by a small air gap from conductive post **33**. When the cavity **13** is excited at its resonant frequency, as by radio frequency energy coupled from waveguide **11**, an intense alternating electric field is established between post **33** and conductive film **41** through crystal **37**. In order to obtain ultra high frequency supersonic waves, crystal **37** is excited at a harmonic considerably above its fundamental. For example, if transducer operation is desired at 3000 megacycles crystal **37** may have a 30 megacycle fundamental and be operated at its hundredth harmonic. Cavity **13** is designed to be electrically resonant at the harmonic frequency, or 3000 megacycles. Critical tuning for resonance of the system is accomplished by rotating bolt **31**.

Supersonic energy developed by crystal **37** may be applied to samples under test by suitable mechanical coupling to quartz supporting block **36**. For test of small liquid samples, the block **36** may be made in the form of a hollow cup and thus serve as a container.

As is generally known, a reciprocal relationship exists for piezoelectric or similar transducers; that is, the system functions equally well for the generation of supersonic waves from applied electrical signals, or for the generation of electrical energy from applied supersonic waves. Accordingly, the apparatus illustrated may be used to convert supersonic vibrations applied to quartz supporting block **36** to electrical signals which may be transmitted through waveguide **11** to a suitable indicator. This permits the adaptation of the apparatus shown as a delay line for pulsed microwave signals. A radio frequency pulse transmitted in waveguide **11** energizes reso-

nant cavity **13** whereby crystal **37** transmits a corresponding pulse of supersonic energy into block **36**. This mechanical wave travels through block **36** and is partially reflected at the discontinuity represented by the end away from crystal **37**. The reflected supersonic energy excites crystal **37**, which in turn establishes an electric field in cavity **13**, returning an electrical signal to the waveguide transmission system **11**. The delay time between input and returned electrical pulses is essentially equal to the total travel time of supersonic energy through quartz block **36**.

It will be noted that the particular construction employed readily permits the removal of wall **15** and its associated quartz block **36** and crystal element **37**. This unit, or cartridge, may be inserted in electrical systems other than the resonant cavity shown, as for example, in the flat side of a waveguide. Upon the application of high intensity electrical fields of a multiple of the crystal resonant frequency, acoustical energy is developed and is coupled from the system through block **36**. The metal film **41** provides a continuous current path under crystal **37** in whatever apparatus the cartridge is employed.

As various modifications and extensions of the principles of the present transducer may now, in view of the above disclosure become apparent to those skilled in the art, it is preferred that the spirit and scope of this invention be limited solely by the appended claims.

What is claimed is:

1. In combination, a resonant cavity, means for energizing said resonant cavity with electromagnetic energy, a piezoelectric crystal, said crystal having as an electrode a conductive film bonded to one of its surfaces, said crystal being secured to said resonant cavity such that said conductive film constitutes a portion of one of the end walls of said resonant cavity, a flexible diaphragm disposed across said cavity, a conductive post secured to one side of said diaphragm and projecting toward said crystal, said post serving as the other electrode of said crystal thereby increasing the electric field acting across said crystal upon energization of said resonant cavity, an output means attached to said conductive film for extracting supersonic energy from said piezoelectric crystal.

2. In combination, a resonant cavity, means for engendering a high frequency electromagnetic field within said cavity, a piezoelectric crystal, a conductive film bonded to one surface of said crystal, said conductive film constituting a portion of one of the end walls of said resonant cavity and serving as an electrode for said crystal, a flexible diaphragm extending across said resonant cavity, a conductive post attached to said diaphragm and extending toward said piezoelectric crystal, said post

serving as the other electrode of said crystal whereby maximum electric field components of the electromagnetic field within said cavity are impressed across said crystal thereby causing the generation of high frequency supersonic waves, and means for axially displacing said diaphragm to tune said cavity to a harmonic of the fundamental frequency of said piezoelectric crystal, and means for coupling supersonic energy from said crystal.

3. In a combination as defined in claim 2 wherein said means for axially displacing said diaphragm within said cavity resonator comprises a spring loaded screw secured to the other end wall of said cavity resonator and bearing upon said diaphragm.

4. In a combination as defined in claim 2 wherein said means for coupling supersonic energy from said crystal comprises a semi-conductive block secured to said conductive film.

5. A transducer comprising a resonant cavity, means for exciting said cavity with electromagnetic energy, a semi-conductive block extending through an end wall of said resonant cavity and having a surface coplanar with the inner surface of said end wall, a piezoelectric crystal, a conductive film bonding a surface of said crystal to said block, said conductive film maintaining electrical continuity of said inner surface of said end wall, a diaphragm extending across said resonant cavity opposite said piezoelectric crystal, a conductive projection attached to one side of said diaphragm and extending towards said piezoelectric crystal, a spring loaded screw bearing upon the other side of said diaphragm for tuning said cavity resonator, said projection serving to increase the electric field component of said electromagnetic energy acting across said piezoelectric crystal.

References Cited in the file of this patent

UNITED STATES PATENTS

2,174,701	Kock	Oct. 3, 1939
2,217,280	Kock	Oct. 8, 1940
2,280,226	Firestone	Apr. 21, 1942
2,404,226	Gurewitsch	July 16, 1946
2,409,321	Shephan	Oct. 15, 1946
2,413,939	Benware	Jan. 7, 1947
2,414,456	Edson	Jan. 21, 1947
2,427,100	Kihn	Sept. 9, 1947
2,463,472	Boch	Mar. 1, 1949

OTHER REFERENCES

Cady: "Piezoelectricity," McGraw-Hill, New York, 1946, pages 678–681.

Cady: "Piezoelectricity," McGraw-Hill, New York, 1946, page 682.