April 3, 1962 T. S. SAAD 3,028,560

ELECTRICAL CRYSTAL UNIT

Filed Jan. 28, 1955

Fig. 1

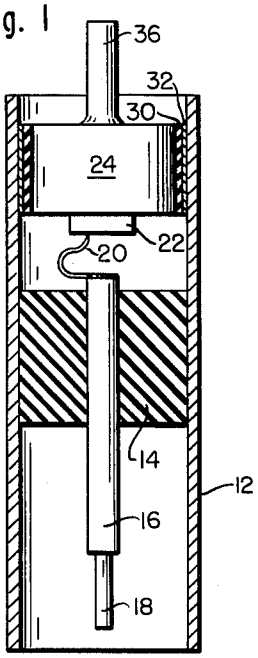


Fig. 2

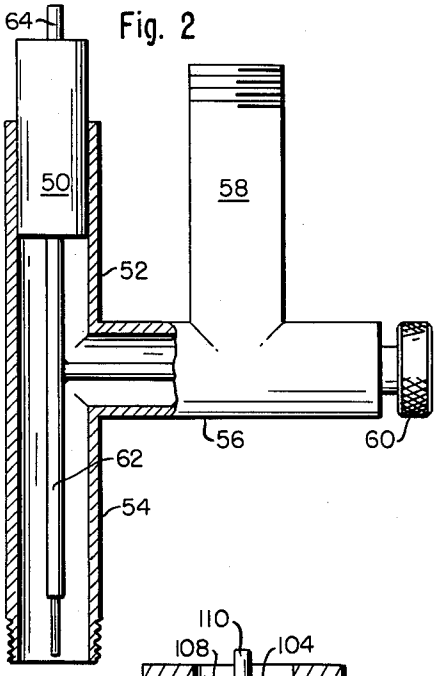


Fig. 3

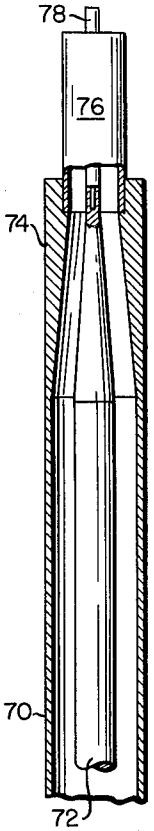


Fig. 6

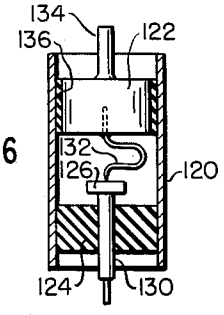
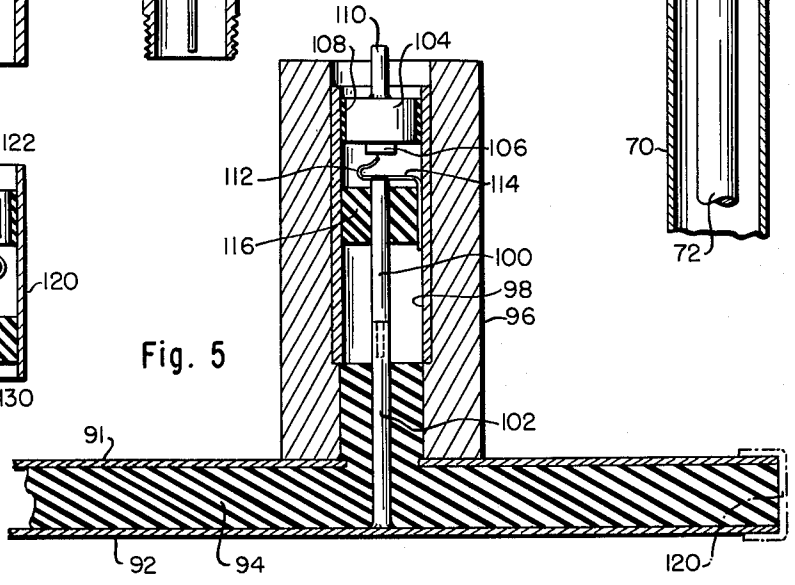


Fig. 5



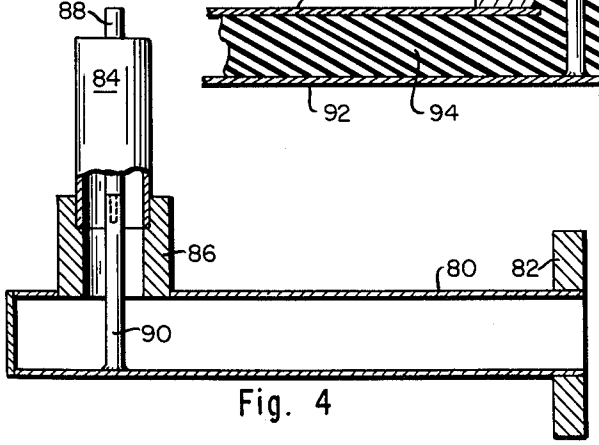


Fig. 4

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ELECTRICAL CRYSTAL UNIT

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2 Claims. (Cl. 329—162)

The present invention relates to microwave apparatus, and more particularly to an improved coaxial crystal cartridge which may be employed as a rectifier, mixer and the like at microwave frequencies.

For the mixer of superheterodyne receivers used at microwave frequencies, it is common practice to employ a crystal diode, rather than a vacuum tube type mixer. Crystals, commonly although not necessarily silicon, afford more favorable signal to noise ratios than the triode or pentode mixers used at lower frequencies. Furthermore, crystals by reason of their small physical size and simple configuration are better suited to effective incorporation within waveguide or coaxial cable transmission systems.

In such systems wherein a crystal mixer is employed, it is necessary to provide suitable connections for the incoming signal (hereinafter termed the R.F. input), the oscillator signal (L.O. or local oscillator), and for the output signal (I.F. signal) resulting from the beating or mixing of the oscillator frequency with the signal frequency. In the conventional coaxial crystal cartridge, the crystal is secured to one face of a metal plug, termed the back plug, that is in direct metallic contact with the shell. The cat whisker that contacts the crystal is carried by a pin that extends through and is supported by an insulating bead fitting within the shell.

In such conventional cartridges, it is necessary to employ a mounting for the cartridge which enables the pin to serve as the input connection for the R.F. signal to the crystal, and also for the I.F. or video output from the crystal. This necessitates the use of an R.F. choke on the output arm of the mounting, to keep the R.F. signal out of the input to the I.F. or video amplifier. Since the choke is effective only over a relatively restricted frequency range, the use of an R.F. choke limits the frequency range over which the assembly is operative, so that broad band operation is not satisfactory.

In addition to the problems involved in the R.F. choke, the conventional crystal cartridge necessitates special provisions in the mounting for the separate I.F. output from the pin carrying the whisker. The conventional crystal mounting also presents connection problems when the crystal is to be used as a simple detector.

It is accordingly an object of the invention to provide a new and improved coaxial crystal cartridge for crystals operating at microwave frequencies, wherein the connections may be made simply and effectively, both for mixer and for detection applications.

It is another object of the invention to provide a coaxial crystal cartridge which makes possible the use of mountings of simplified construction and affording wide band operation at microwave frequencies.

Still another object of the invention is to provide a coaxial crystal cartridge having means within the cartridge for effectively isolating the R. F. input from the I.F. or video output, so as to eliminate the necessity for isolating means in the mounting structure for the cartridge.

A further object of the invention is to provide a coaxial crystal cartridge that may be effectively employed with wave guide, with coaxial lines, and with microstrip feed systems to afford simple and compact installation and efficient operation at microwave frequencies.

The invention has as still another object the provision

of a crystal cartridge wherein a self-contained direct current return path may readily be provided when desired.

With these and other objects in view, the present invention contemplates as a feature thereof a crystal cartridge wherein the plug is electrically isolated from the shell in such a manner as to provide determined reactive characteristics.

More specifically, it is a feature of the invention to provide, between the plug and the shell of the cartridge, a capacitive reactance such that there exists an effective by-pass to R.F. frequencies while affording a substantially open circuit for signals within the I.F. or video range. By providing for connection to the I.F. system at the outer end of the plug, the crystal may effectively be coupled to the I.F. amplifier while the R.F. signal is substantially by-passed. The elimination of the R.F. choke not only simplifies the construction of the mounting for the cartridge, but also permits relatively broad band operation. Since the new crystal cartridge provides its own output connection at the plug end as an integral part of the cartridge, independent coaxial input and output connections thereby are provided at opposite ends of the device. Thus the device may conveniently be termed a feed-through crystal cartridge and such designation is hereinafter employed.

In the drawings illustrating the invention according to its several embodiments,

FIG. 1 is a view in sectional elevation on a somewhat enlarged scale, showing the novel feed-through cartridge construction.

FIG. 2 illustrates the use of the feed-through crystal as a mixer in a coaxial line.

FIG. 3 shows the cartridge mounted in a coaxial line for use as a simple detector.

FIG. 4 illustrates the manner of mounting the feed-through cartridge for use as a waveguide mixer.

FIG. 5 shows in sectional elevation a slightly modified form of feed-through crystal cartridge, embodying an integral D.C. return, with the cartridge shown mounted for use with so-called microstrip or microwave strip transmission line.

FIG. 6 illustrates in sectional elevation a feed-through crystal device alternative to that of FIG. 1.

The crystal cartridge illustrated in FIG. 1 comprises a shell 12 of conductive material with an insulating bead 14 through which extends the pin 16. The diameter of the shell is such as to permit appropriate connection to the outer conductor of coaxial cable to which the device may be connected. The outer end of the pin is reduced at 18 to make telescoping connection with the center conductor of the cable. The other end of the pin carries the cat whisker 20 which may be of the usual resilient wire construction, pointed for contact with the crystal.

The crystal element 22, which may be of silicon, germanium or other suitable semi-conductor exhibiting appropriate rectifying properties, is mounted, as by soft soldering, to the inner face of the metallic back plug 24. The spacing between back plug 24 and bead 14 is such as to provide the desired contact pressure between whisker and semi-conductor surface when the point of the whisker has been located on the desired spot on the semi-conductor surface.

The back plug 24 of the crystal unit, unlike conventional coaxial cartridge constructions, is not in direct metallic contact with the shell 12 (which results in zero impedance at all frequencies including D.C.), but instead is insulated therefrom in a particular manner and in such fashion as to afford novel and useful results. In the coaxial crystal device of FIG. 1, the back plug is insulated from the sleeve by a thin film or sleeve 30 of dielectric material of effective insulating properties. By way of example, the insulating sleeve may be an epoxy resin, a

polyester resin, a copolymer comprising polymerized dichlorostyrene such as identified by the trademark Styron, or a tetrafluorethylene resin such as that designated by the trademark Teflon. For convenience, the dielectric material may be disposed between the plug 24 and a thin metallic jacket or sleeve 32 to facilitate insertion of the insulated plug within the main shell 12 which forms the envelope of the cartridge.

The insulation of the plug from the shell results in D.C. isolation of the crystal and its supporting plug from the shell or outer conductor 12. More importantly, the effect of the insulating sleeve is to constitute a condenser of small capacity which may be made effective to by-pass or short-circuit certain frequencies while having no appreciable effect on relatively lower frequencies. Thus, where the crystal is employed as a mixer or a video detector, the insulating sleeve intermediate the shell and plug results in a low-capacity condenser of coaxial configuration, the capacity of which may be made such as to by-pass effectively the R.F. signal while causing no substantial attentuation of the desired I.F. or video output signal resulting from mixer action.

Because of this selective by-pass effect, it becomes possible to derive the crystal output directly from the back plug 24, and for this purpose the plug is provided with a terminal 36, to which the center conductor of coaxial cable may be connected for feeding an I.F. amplifier or the like. The crystal device thus becomes a true coaxial element with feed-through from one end to the other, the input being applied to the pin end and the rectified or mixer output, as the case may be, derived coaxially from the other end and with an integral coaxial R.F. by-pass condenser directly associated with the crystal support.

By way of example of the capacity values readily attainable with the integral coaxial by-pass condenser, a device employing a shell of 0.188" inside diameter and an insulating sleeve 0.004" thick, formed of an epoxy resin having a dielectric constant of 2.0, the plug length being approximately 0.188" long, provides a capacitance of approximately 12 $\mu\mu$f. This is a value that provides a reactance of the order of an ohm or less, at frequencies higher than about 1000 megacycles per second, so as to by-pass effectively the R.F. energy. The I.F. output, being at considerably lower frequency, is not seriously attenuated, as the small capacitance presents a relatively high impedance at such frequencies.

The utilization of the feed-through crystal device in mixer applications is illustrated in FIG. 2. In this embodiment, which is for use with coaxial lines, the feed-through crystal cartridge indicated at 50, is mounted in arm 52 of the coaxial mixer. Arm 54 connects to the coaxial line that feeds the R.F. signal to the crystal, while arm 56 injects the local oscillator signal, the oscillator being connected at 58 with the injection controlled in the usual manner by adjustment knob 60. The center conductor 62 connects to the pin of the cartridge in the manner described in FIG. 1, while the I.F. output from the mixer is obtained from the pin 64 on the crystal back plug.

The feed-through cartridge is likewise effective in crystal rectifiers and detectors at microwave frequencies. FIG. 3 illustrates the improved crystal device mounted at the end of a coaxial cable to serve as a simple detector. The R.F. signal is supplied by coaxial line having outer conductor 70 and center conductor 72. A tapered fitting 74 provides a match to the crystal 76, the body of which is received in the end of the fitting.

Instead of requiring the conventional video output network which unduly complicates the crystal connection to the end of the line, the new feed-through crystal cartridge construction makes it possible to derive the video output directly from the back plug terminal 78, with the R.F. energy effectively by-passed by the integral coaxial condenser formed by the insulating dielectric sleeve between body and back plug, as shown in FIG. 1. For the D.-C. return, the usual connection may be provided in the coaxial line, or the integral D.-C. return hereinafter described and illustrated may conveniently be employed.

The advantages of the feed-through crystal when utilized as a mixer in waveguide installations will be readily apparent from FIG. 4. Here the mixer waveguide section is indicated at 80, with flange 82 for connection to the waveguide through which the R.F. signal and the local oscillator energy are supplied. The crystal unit is shown at 84 mounted in coaxial fitting 86 on one wall of the guide, with the center connection extending to the opposite wall of the waveguide by conductor 90 to provide the D.-C. return.

Here again, instead of requiring an elaborate choke construction in the waveguide mounting and connected via the center conductor 90 to provide the I.F. output, it is merely necessary to connect to the terminal 88 on the specially-mounted back plug, as shown in FIG. 1 and described. Like the coaxial mixer construction of FIG. 2, the R.F. energy is effectively by-passed, for a wide range of frequencies, by the coaxial by-pass condenser that is an integral part of the crystal cartridge.

A further example of the use of the feed through crystal as embodied in microstrip waveguide is shown in FIG. 5. Here the waveguide elements are the strips 91 and 92, with insulated spacing material 94. The coaxial fitting 96 secured to strip 91 provides a mounting for the shell 98 of the cartridge, with the center pin 100 connected to the bottom strip 92 through short conductor 102.

In this embodiment, the back plug 104 on which the crystal 106 is mounted is spaced from the shell 98 solely by the dielectric sleeve 108. For dielectric materials having physical properties that permit convenient assembly of the plug within the shell, the separate metal sleeve 32 illustrated in FIG. 1 may be omitted. As in the other embodiments, the back plug carries the coaxial terminal 110 that provides the feed-through output connection.

This embodiment likewise serves to illustrate a further feature of the invention, it being understood that such feature is in no way limited to cartridges for microstrip applications but may be used wherever crystals having an integral D.-C. return are desired, for example, with probe-type connections where no direct return exists. In this construction, the whisker 112 is provided with an extension 114, or, alternatively, a separate lead is provided, from the inner end of whisker pin 100. This lead extends radially to the shell, and then along the inner wall thereof, being firmly held in position between the insulating bead 116 and the shell 98. This D.-C. return is readily provided at the time of assembling the crystal device, the lead being laid along the outside of the insulating bead and the bead then forced into place within the shell.

In the event, in this microstrip application of the feed-through crystal, no integral D.-C. return is provided, an external return may be employed as indicated at 120 by the dotted-line short across the strips 91, 92 at the end of the arm.

While the invention has so far been described as embodied in constructions in which the crystal element is carried by the plug, and the whisker by the insulating bead, this is of course not the only arrangement possible. FIG. 6 illustrates the feed-through crystal features in a crystal cartridge in which the crystal element and catwhisker are interchanged from their positions shown in FIG. 1.

In this embodiment the shell is indicated at 120, the conductive plug element or back plug at 122, and the insulating bead at 124. The crystal 126 is soft soldered to a pin 130 extending through the bead to provide the coaxial connection to the crystal element thereon. The catwhisker 132 is carried by the conductive plug 122, with terminal 134 on the outer end of the plug providing the feed-through coaxial connection as previously described.

The conductive plug, as in the other embodiments, is

electrically insulated from the shell (with respect to D.C.) by a thin film or sleeve of dielectric material **136**. The sleeve thickness is such as to retain the plug securely in position, with the gap between the inner surface of the metallic shell and the outer surface of the plug providing the required capacitive reactance for proper by-passing at the operating frequency. No integral D.C. return is shown in this embodiment, but one may readily be provided, when required, by extending a conductor from the crystal supporting pin **130** into jamming relation between bead and shell, as is done with the D.C. return **114** in FIG. 5 from the whisker support.

FIGS. 2, 3, 4 and 5 of the drawings are to be considered as merely illustrative of typical mounting arrangements wherein the advantages of the novel feed-through crystal are effectively realized, when compared with the relatively complex arrangements heretofore employed. Other forms and constructions for utilizing the integral by-pass crystal cartridge of the present invention will be apparent to those skilled in the art.

Tests of apparatus embodying crystal cartridges constructed in accordance with the invention have indicated that wide band performance is effectively realized. Thus, measurements of tangential sensitivity of video detector units have shown relatively high and uniform response characteristics over a frequency range from 1000 to over 10,000 megacycles per second. Thus it appears that effective R.F. by-passing occurs over a very substantial frequency range, as compared with the uneven or limited response that results when conventional crystal devices and mounting means therefor involving the usual R.F. choke or other narrow-band means are employed.

I claim:

1. A crystal cartridge for microwave apparatus comprising a conductive shell, a conductive back plug on which the crystal is mounted, a whisker, an insulating support for said whisker within and directly engaging said shell and supported thereby, a coaxial input extending through and mounted to the insulating support and making connection to said whisker, a coaxial output connection on the back plug, said plug and said insulating support having a fixed spacing therebetween which establishes rectifying contact between said crystal and said whisker, said fixed spacing being maintained by the secure mounting of said plug and said insulating support within said conductive shell, a thin metal sleeve surrounding the back plug and in electrical contact with the interior of the shell, and dielectric material between the metal sleeve and back plug to form a coaxial capacitor having low impedance at microwave frequencies.

2. A crystal cartridge for microwave frequencies comprising a conductive shell, cooperating crystal and catwhisker elements within the shell, a conductive plug at a position within the shell adjacent one end thereof on which said crystal is mounted, means securing the plug in said position, said means comprising a thin insulating sleeve of dielectric material intermediate the plug and shell, the plug, the shell and the means securing the plug in position forming a coaxial R.F. by-pass condenser, a conductive pin on which the catwhisker element is mounted, an insulating support for said pin directly engaging the shell and supported thereby at a position therein spaced along the shell at a fixed distance from the plug and said insulating sleeve, said pin extending through and secured in the insulating support, the catwhisker element being mounted at the end of said pin lying within the space between the support and the plug, the fixed distance between the insulating support and the conductive plug establishing rectifying contact between the catwhisker element and the crystal, and a conductor extending from the catwhisker end of the pin into contact with the shell providing a D.C. path from catwhisker to shell, the shell and plug affording coaxial output connections and the shell and pin affording coaxial input connections for the cartridge.

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