Sept. 26, 1961 J. W. DEES 3,002,155

MICROWAVE BROADBAND CRYSTAL HOLDER FOR CARTRIDGE TYPE CRYSTALS

Filed March 21, 1958

Fig. 1.

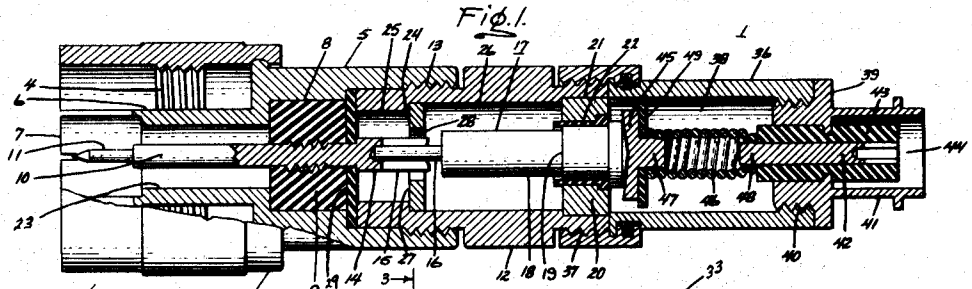


Fig. 2.

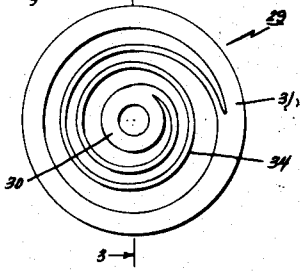


Fig. 3.

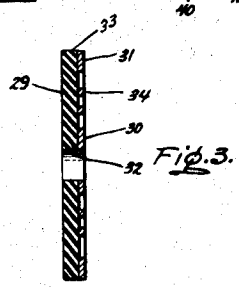


Fig. 4.

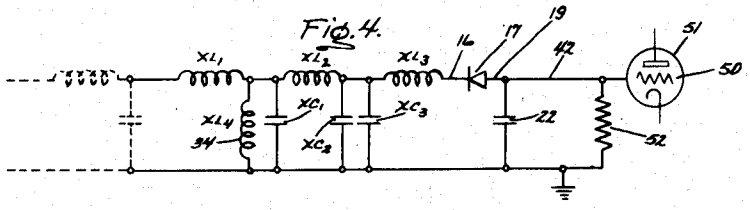


Fig. 5.

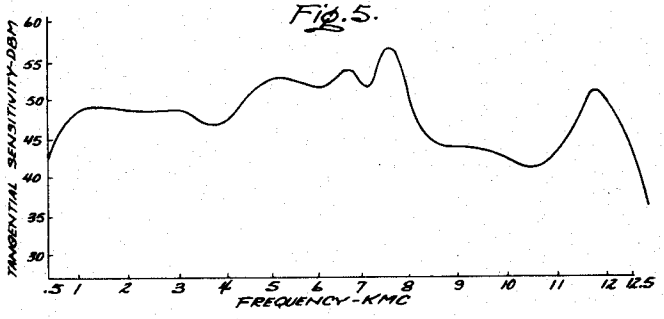
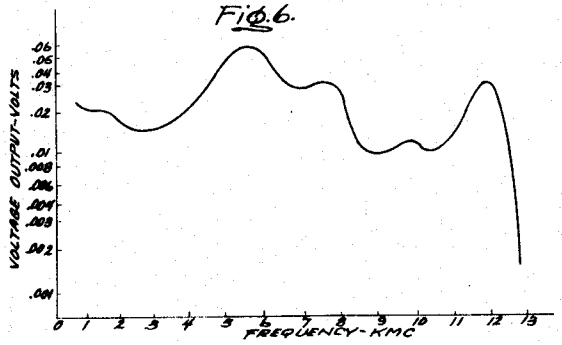


Fig. 6.



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3,002,155

MICROWAVE BROADBAND CRYSTAL HOLDER FOR CARTRIDGE TYPE CRYSTALS

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11 Claims. (Cl. 329—162)

This invention relates generally to microwave transmission lines, and more particularly to a cartridge type crystal holder for use with a coaxial microwave transmission line.

In certain microwave receiving system, it has been customary to mount a cartridge type crystal detector concentrically within a coaxial transmission line, i.e., within the outer conductor and serially connected to the inner conductor of the line. Certain of these systems are required to operate over a very wide frequency range, i.e., for example 500 megacycles to 12,000 magacycles, however, to the best of the present applicant's knowledge, coaxial crystal holders for cartridge type crystals have not been available which were capable of providing good tangential sensitivity over such a frequency range. Furthermore, many such receiving systems require a direct current return path for the detected signal, i.e., rectified current passed by the crystal detector and to the best of the applicant's knowledge, coaxial crystal holders have not been available with an internal direct current return path which would operate satisfactorily from 500 megacycles to 12,000 megacycles.

While various coaxial crystal holders for cartridge type crystals for use with coaxial microwave transmission lines are presently available, it has been generally necessary to utilize several different holders to cover the range of frequencies from 500 megacycles to 12,000 megacycles in order to maintain reasonable sensitivities. Some crystal holders known to the applicant employ padding, or an intentionally introduced lossy network to reduce input VSWR (voltage standing wave ratio). However, in these crystal holders, the frequency range is limited by the characteristics of the lossy network and necessarily sacrifices sensitivity for frequency response or band width. In such crystal holders, the padding introduced can, depending upon the type employed, provide a direct current return path, however, in such cases the upper frequency response has been generally limited to about 3 or 4 thousand magacycles and the sensitivity of detection is reduced by the amount of the padding employed. Direct current return paths have also been provided in coaxial crystal holders by other methods, such as the employment of a short-circuited stub both as a tuning device and a direct current return; this method, however, necessarily provides narrow band performance. In addition, coaxial crystal holders have been provided with a fine straight wire connected between the center conductor and the outer conductor to provide the direct current return path, however, while this method provides excellent high frequency response, it cannot be used below about 3 or 4 thousand megacycles.

There are available coaxial crystal holders for the tripolar or coaxial type crystals which provide broadband operation from about 100 megacycles to 12,400 megacycles, and with satisfactory sensitivity. Such crystals are, however, far more expensive than the cartridge type crystals and the sensitivity of such crystal holders is attributable to the crystal and not to the crystal holder construction. However, even such coaxial crystal holders for tripolar or coaxial crystals do not have an internal direct current return path; some tripolar crystals are provided with a fine straight wire direct current return path or a coiled wire direct current return, however, these arrangements are limited in operation down to about 1,000 megacycles. With these exceptions, the direct current return path must be provided externally.

It is therefore desirable to provide a coaxial crystal holder for cartridge type crystals which will provide broadband operation, i.e., wide band frequency response, for example, from 500 megacycles to 12,000 megacycles, without sacrificing sensitivity. It is of course necessary that such a crystal holder be capable of employment with presently commercially available standard cartridge-type crystals and it is further desirable that the arrangement provide good tracking characteristics as well as low crystal spread over the entire frequency band; "crystal spread" is a measure of the difference in output voltage obtained using a number of unselected crystals of the same type at any specified frequency, input power level and crystal load impedance, while "tracking" refers to the property of two or more unselected crystals of the same type to provide the same output voltage characteristic over the entire frequency range. It is additionally desirable that such a broadband crystal holder provide an internal direct current return path which will operate satisfactorily down to at least 500 megacycles thereby eliminating the need to provide an external direct current return path in other circuit elements on the RF or input side of the crystal detector. Such a direct current return path must not interfere with the RF input signal, i.e., it must act as a very high RF shunt impedance, in order not to reflect RF energy and thereby introduce undesirable signal loss into the system.

It is therefore a general object of this invention to provide an improved broadband coaxial microwave crystal holder for cartridge type crystals.

Another object of this invention is to provide an improved broadband coaxial crystal holder for cartridge type crystals incorporating an internal direct current return path which will operate in a satisfactory manner down to at least 500 megacycles.

A further object of this invention is to provide an improved broadband microwave crystal holder for cartridge type crystals in which the tracking properties and crystal spread characteristics are improved over those heretofore provided by prior crystal holders over a wide frequency range.

It is a specific object of my invention to provide an improved broadband crystal holder for use with cartridge type crystals which will provide a tangential sensitivity in excess of —40 dbm from 500 megacycles to 12,000 megacycles and an output voltage in excess of ten millivolts at an input power level of —20 dbm using a crystal load impedance of from 5,000 to 10,000 ohms and a forward bias current of from ten to seventy microamperes over the entire frequency range and using any number of unselected crystals of the same type.

My invention, in its broader aspects, therefore, provides a coaxial microwave crystal holder for cartridge type crystals adapted to be connected to a coaxial microwave transmission line and having concentric inner and outer conductors with a crystal concentrically disposed within the outer conductor and serially connected with the inner conductor. The portion of the transmission line of which the crystal holder effectively forms a part has a first portion on the RF (radio frequency) side of the crystal having a first characteristic impedance and a second portion adjacent the crystal having a second characteristic impedance higher than the first characteristic impedance; I have found that increasing the characteristic impedance adjacent the crystal increases the sensitivity of the device over the desired wide frequency range which in turn improves the crystal spread and the tracking characteristics. In the preferred embodiment of my invention, the outer conductor has a step formed in its inner surface in general alignment with the RF terminal of the crystal car-

tridge, the step effectively dividing the outer conductor into a first portion extending on the RF side of the crystal cartridge with a first inside diameter thereby providing a first characteristic impedance, and a second portion extending in the opposite direction from the first portion and generally coextensive with the crystal cartridge, with its second inside diameter greater than the first inside diameter thereby providing a second characteristic impedance greater than the first characteristic impedance. An annular conductive member extends inwardly from the second portion of the outer conductor adjacent the step and having its center opening surrounding and spaced from the RF terminal of the crystal cartridge thereby providing a capacitive iris therewith.

In order to provide the direct current return path, in accordance with the broader aspects of my invention, I provide a flat spiral conductor surrounding the inner conductor and having its inner end connected to the inner conductor on the RF side of the crystal and having its outer end connected to the outer conductor thereby providing high RF impedance and low direct current resistance. In the preferred embodiment of my invention, an annular member of insulating material is provided surrounding the portion of the inner conductor connected to the RF terminal of the crystal cartridge and extending outwardly to the first portion of the outer conductor. A spiral conductor is supported on one side of the annular insulating material surrounding the inner conductor with its inner end connected thereto and its outer end connected to the outer conductor.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a side-elevational view, partly in section and partly broken away, illustrating a coaxial microwave crystal holder incorporating my invention;

FIG. 2 is an end view of the spiral direct current return path incorporated in FIG. 1;

FIG. 3 is a cross-sectional view of the spiral return path of FIG. 2 taken along the line 3—3;

FIG. 4 shows a simplified equivalent circuit for the device of FIG. 1 useful in explaining my invention;

FIG. 5 shows a plot of tangential sensitivity against frequency obtained with a crystal holder incorporating my invention; and

FIG. 6 is a plot showing voltage output against frequency obtained with a crystal holder incorporating my invention.

Referring now to FIGS. 1, 2 and 3, my improved broadband crystal holder, generally identified as **1**, includes at its RF or input end, a generally conventional type N connector **2** adapted to be connected to a coaxial transmission line. The connector **2** comprises an outer metallic sleeve portion **3** having internal threads **4** formed therein for securing the device to mating external threads on the connector of the associated coaxial transmission line. Sleeve portion **3** of connector **2** is rotatably connected to body portion **5** formed of any suitable conductive metal, such as silver plated brass. Body portion **5** has a cylindrical part **6** extending within sleeve member **3** of connector **2** which terminates in a plurality of resilient segments **7** adapted to be inserted in a conventional type N connector, as is well known in the art. Body portion **5** has an enlarged cavity **8** formed therein communicating with the bore **23** of its cylindrical part **6** and a block of suitable insulating material such as polytetrafluoroethylene (known by the Du Pont trademark Teflon) **9** is positioned in the cavity **8** and supports center pin **10** concentrically within the cylindrical part **6**. The center pin **10**, which may be made of any suitable conductive material, such as beryllium copper has an end portion **11** adapted to mate with a corresponding female portion of the center conductor of a type N connector; it will now be seen that the cylindrical part **6** of the body portion **5** and the coaxial center pin **10** respectively form the outer and inner conductors of a segment of coaxial transmission line.

An essentially tubular member **12**, likewise formed of any suitable conductive material, such as silver plated brass, is provided with body portion **5** being removably secured thereto, as by threaded connection **13** on the exterior surface of the tubular member **12**. Center pin **10** has a portion **14** extending coaxially into tubular member **12** with suitable resilient fingers **15** formed on its end for engaging the pin terminal **16** of a suitable cartridge-type crystal detector **17**.

Cartridge type crystal detector **17** conventionally has a generally cylindrical body portion **18**, generally formed of ceramic material, with a metal sleeve portion **19** forming the other terminal. The metal sleeve portion **19** of the cartridge crystal **17** is supported coaxially within the tubular member **12** by means of an annular insert member **20** seated in a machined recess **21** in the bore of tubular member **12** with an annular sleeve **22** of suitable insulating material, such as nylon, separating the metal sleeve **19** and the annular insert member **20**; the annular insert member **20**, together with the insulating sleeve **22** and the metallic terminal **19**, on the crystal detector **17**, cooperate to form a capacitive connection between the terminal **19** and the tubular member **12**, as will be hereinafter more fully described.

The inner surface of the tubular member **12** has a step **24** formed therein in general alignment with the pin terminal **16** of crystal **17** and thus dividing the tubular member **12** into a first section **25** and a second section **26**. It will readily be seen that the section **25** of the tubular member **12** extends toward the RF end of the assembly and has a smaller inside diameter than does the other section **26** which extends generally coextensively with the crystal **17** and has a larger inside diameter than the section **25**. An annular conductive iris member **27** is provided seated within the section **26** of the tubular member **12** and preferably abutting the step **24**. Annular member **27** has its central opening **28** coaxially surrounding and spaced from the resilient fingers **15** on the end **14** of the center pin **10**, thus forming a capacitive connection therewith, which will be hereinafter more fully described. In assembling the tubular member **12** and the annular iris member **27** and annular insert member **20**, which are all preferably formed of brass, the annular iris member **27** is first inserted into the section **26** of the tubular member **12** and soldered into position abutting the step **24**, the annular insert member **20** is then inserted into the recessed portion **21** and soldered in place, and the resulting assembly is then preferably silver plated as a unit.

Referring now to FIGS. 2 and 3 in addition to FIG. 1, my improved direct current return path comprises a flat annular or washer-shaped member **29** formed of suitable insulating material, such as an epoxy resin-glass laminate. Conductive rings **30** and **31** are respectively supported on one face of the member **29** adjacent the central opening **32** and outer periphery **33**, these conductive rings **30** and **31** being interconnected by a spiral conductor **34** also supported on the face of the member **29**, i.e., the spiral conductor **34** surrounds the central opening **32** and conductive ring **30** with its inner end connected thereto and with its outer end connected to the outer conductive ring **31**. The member **29** with the conductive rings **30** and **31** and the spiral conductor **34** supported thereon may be formed by one of the well known printed circuit techniques. For example, the epoxy-glass laminated member **29** may be initially copper clad on one side, i.e., having a layer of copper deposited on one side. A photosensitive acid resist material is then applied to the copper surface and the same is then exposed to light, generally ultraviolet, through a photographic negative of the de-

sired conductor pattern, i.e., a photographic negative corresponding to the configuration of the inner and outer conductive rings **30** and **31** on the spiral conductor **34**. The exposed member is then developed, typically by baking, which hardens the portions of the photoresist material which have been exposed to light and the unexposed portions are then etched away, for example in a ferric chloride bath, thereby leaving the desired conductive pattern on the surface of the member **29** as shown in FIGS. 2 and 3. Insulating member **29** with conductive rings **30** and **31** and the spiral conductor **34** supported thereon is positioned with center pin **10** extending through the central opening **32** and with its portion **14** abutting the center conductive ring **30** and thus in electrical contact therewith, and with the end of tubular member **12** likewise abutting the outer conductive ring **31** and therefore also in electrical contact therewith. While I have employed the photoetching process for producing the direct current return members described above, it will be readily understood that other printed circuit techniques well known in the art may be employed. It will be further understood that while in the particular embodiment shown, a spiral conductor **34** of about three turns was found to provide the desired high RF impedance and satisfactory operation down to at least 500 megacycles, satisfactory functioning at lower frequencies may be obtained by a suitable variation of the number of spiral turns and the size of the spiral line.

In order to complete the assembly, another body portion **36** is provided formed of suitable conductive material, such as silver plated brass, and having a threading engagement, as at **37** with the tubular member **12**. Body portion **36** defines a cavity **38** which is closed by a conductive member **39** threadingly engaged with corresponding internal threads at the end of the body portion **36**, as at **40**, and which has a cylindrical extension portion **41** forming a part of a conventional BNC connector. A center pin **42** is provided formed of suitable conductive material, such as beryllium copper, pin **42** being supported by suitable insulating material **43**, such as polytetrofluoroethelene, which in turn is supported by means of the plug member **39** as shown. Center pin member **42** has conventional resilient segments **44** formed at its end for engagement with a complementary center pin of a type BNC connector as is well known in the art. The electrical connection between the center pin **42** and the terminal **19** of the crystal **17** is formed by a contact member **45** which is urged against terminal **19** of crystal cartridge **17** by means of a suitable coil spring **46**, likewise formed of suitable conductive material such as beryllium copper; one end of spring **46** embraces a portion **47** of the contact member **45** and the other end embraces end **48** of the center pin **42**, all within cavity **38** formed by body portion **36**. A suitable annular or washer shaped member **49** formed of suitable insulating material, such as Teflon, surrounds portion **47** of the contact member **45** and serves as a guide for the contact member **45** within the cavity **38**.

In prior untuned arrangements of coaxial crystal holders for cartridge type crystals known to the applicant, it was found that the sensitivity fell off very rapidly above about 7,000 megacycles. The provision of the step **24** in the tubular member **12** thereby increasing the characteristic impedance of the coaxial line in the region of the crystal cartridge, together with the provision of the capacitive iris **27** was found to provide satisfactory sensitivity as high as 12,000 megacycles. The exact location of the step **24** and its magnitude were determined emperically since the geometry and characteristics of cartridge type crystals do not lend themselves readily to accurate impedance calculations. It is the applicant's belief however, that the optimum improvement in sensitivity is obtained by locating the step **24** adjacent the RF end of the crystal cartridge **17** and with the inside diameter of the portion **26** of the tubular member **12** being on the order of ten percent greater than the inside diameter of the portion **25**. The optimum position of the iris **27** and the diameter of its central opening **28** likewise was emperically determined since again, the applicant is unaware of any satisfactory method of calculation, however, it was found that the optimum position of the iris was at the same point along the coaxial input line as the step **24** and it is the applicant's belief that an aperture **28** therein having a diameter approximately one-half the inside diameter of the portion **26** of tubular member **12** will provide generally satisfactory results.

It will be understood that the stepped impedance provided by the step **24** is of such a nature that a higher coaxial line characteristic impedance exists along the line toward or closer to the crystal. In FIG. 4 there is shown a simplified equivalent circuit for the device of FIG. 1, it being understood that FIG. 4 is not intended to portray an accurate equivalent circuit which could be freely substituted for the device of FIG. 1. It will be recalled that lumped impedances, i.e., series inductance and shunt capacitance can generally be substituted for a coaxial transmission line and thus, in FIG. 4, the series inductance identified as X_{L1} indicates the distributed inductance of the coaxial line to which the crystal holder **1** is connected, X_{L2} identifies the distributed inductance of the portion of the line to the left of the step **24**, i.e., that defined by the portion **25** of the tubular member **12**, and X_{L3} identifies the higher distributed inductance of the increased inside diameter portion **26**. Likewise, the shunt capacitance identified as X_{C1} indicates the distributed capacitance of the coaxial transmission line to the left of the step **24**, the shunt capacitance identified as X_{C2} indicates the shunt capacitance introduced by virtue of the step **24**, and the shunt capacitance X_{C3} indicates the shunt capacitance introduced by the iris member **27**. It will also be seen that the shunt inductance X_{L4} in the spiral conductor **34** connected between the tubular member **12** and the center pin **10** provides a high RF impedance, and a low direct current resistance return path for the rectified or detected current passed by the crystal **17**. It will now be seen that the capacitor formed by the insulating sleeve **22** separating the terminal **19** of crystal cartridge **17** and the annular conductive member **20** forms an RF by-pass capacitor for by-passing any RF energy (or signal) which is passed by the crystal **17** to ground. It will be readily understood that the center pin **42** may be connected to the grid **50** of a suitable amplifier **51** with grid resistance **52** constituting the load impedance for the crystal **17**. It will be further readily understood that employment of a different type of crystal cartridge will introduce different geometry into the system and may necessitate suitable adjustment in the positioning of the step **24**, the relative inside diameters of the sections **25** and **26**, the location of the capacitive iris **27** and the proportioning of the center opening **28** therein.

A crystal holder in accordance with FIG. 1 has been constructed for use with type MA–408A and 1N23C cartridge crystals. In this device, the tubular member **12** had a length of .955 inch with section **25** being .250 inch long and having an inside diameter of .375 inch and with portion **14** of center pin **10** having an outside diameter of .156 inch, thereby to provide an input characteristic impedance of approximately 50 ohms. Portion **26** of the tubular member **12** was .505 inch long and had an inside diameter of .437 inch; iris **27** was .050 inch long with an inside diameter of .221 inch. The direct current return path member **29** was photoetched on copper clad epoxy laminate .004 inch thick with the copper layer being .0014 inch thick, conductive rings **30** and **31** being respectively .020 and .095 inch wide and the spiral conductor **34** having approximately three turns .005 inch wide.

Referring now to FIG. 5, there is shown a plot of the tangential sensitivity characteristic of the coaxial microwave crystal holder described above, employing an MA–408A type crystal feeding a video amplifier having a bandwidth of 3.5 megacycles, the load resistor **52** having

10,000 ohms and a bias of 50 microamperes being provided. It will be seen that in the frequency range from 500 to 12,000 megacycles, the tangential sensitivity is at all times in excess of —40 dbm, actually varying between about —42.5 and —57 dbm. Likewise referring to FIG. 6 which is a plot of the voltage output of the same crystal holder against frequency with a power input level of —20 dbm, it is seen that the voltage output is at all times in excess of 10 millivolts over the range from 500 to 12,000 megacycles.

It will now be seen that I have provided a broadband coaxial crystal holder for cartridge type crystals for use with a coaxial transmission line at microwave frequencies which provides satisfactory sensitivity and voltage output over an extremely wide range of frequencies, i.e., 500 to 12,000 megacycles, and which also incorporates an internal direct current return path, which operates satisfactorily down to the lower frequency, i.e., 500 megacycles.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention.

What is claimed is:

1. For use with a coaxial microwave transmission line having concentric inner and outer conductors, a crystal holder for cartridge type crystals comprising: an outer generally tubular member formed of conductive material and adapted to be connected to said outer conductor of said transmission line; a crystal coaxially disposed within said tubular member and having one terminal adapted to be connected to said inner conductor of said transmission line; said tubular member having a first portion toward said transmission line providing a first characteristic impedance for said holder, said tubular member having a second portion remote from said transmission line providing a second characteristic impedance greater than said first characteristic impedance; said crystal being concentrically and axially disposed inside said second portion; capacitor means between said tubular member and said one crystal terminal; capacitor means between said tubular member and the other terminal of said crystal; and a spiral conductor having its inner end connected to said one terminal of said crystal and its other end connected to said tubular member for providing a high radio frequency impedance return path for rectified current passed by said crystal.

2. In combination: a section of coaxial microwave transmission line having concentric inner and outer conductors; a cartridge type crystal connectrically disposed within said outer conductor and serially connected with said inner conductor; said transmission line having a first portion on the radio frequency side of said crystal having a first characteristic impedance and a second portion adjacent said crystal having a second characteristic impedance higher than said first characteristic impedance; said second portion being axially coextensive with said crystal; and capacitor means between said outer conductor and said inner conductor on the radio frequency side of said crystal.

3. In combination: a section of coaxial microwave transmission line having concentric inner and outer conductors; a cartridge type crystal concentrically disposed within said outer conductor and serially connected with said inner conductor; said transmission line having a first portion on the radio frequency side of said crystal having a first characteristic impedance and a second portion adjacent said crystal having a second characteristic impedance higher than said first characteristic impedance; said second portion being substantially axially coextensive with said crystal; and an annular conductive member extending inwardly from said outer conductor and having its center opening surrounding and spaced from said inner conductor on the radio frequency side of said crystal thereby forming a capacitive iris therewith.

4. In combination: a section of coaxial microwave transmission line having concentric inner and outer conductors; a generally tubular crystal cartridge concentrically disposed within said outer conductor and having its terminals serially connected with said inner conductor; said outer conductor having a step formed in its inner surface in general alignment with the radio frequency terminal of said crystal cartridge, said step dividing said outer conductor into a first portion extending on the radio frequency side of crystal cartridge with a first inside diameter thereby providing a first characteristic impedance and a second portion extending in the opposite direction from said first portion with a second inside diameter greater than said first inside diameter thereby providing a second characteristic impedance greater than said first characteristic impedance; and an annular conductive member extending inwardly from said second portion of said outer conductor adjacent said step and having it center opening surrounding and spaced from said radio frequency terminal of said crystal cartridge thereby forming a capacitive iris therewith.

5. In combination: a section of coaxial microwave transmission line having concentric inner and outer conductors; a generally tubular crystal cartridge concentrically disposed within said outer conductor and having its terminals serially connected with said inner conductor; said outer conductor having a step formed in its inner surface in general alignment with the radio frequency terminal of said crystal cartridge, said step dividing said outer conductor into a first portion extending on the radio frequency side of crystal cartridge with a first inside diameter thereby providing a first characteristic impedance and a second portion extending in the opposite direction from said first portion with a second inside diameter greater than said first inside diameter thereby providing a second characteristic impedance greater than said first characteristic impedance, said second inside diameter being approximately 10% greater than said first inside diameter; and an annular conductive member extending inwardly from said second portion of said outer conductor adjacent said step and having its center opening surrounding and spaced from said radio frequency terminal of said crystal cartridge thereby forming a capacitive iris therewith, the inside diameter of said annular member being approximately one-half of the inside diameter of said second portion of said outer conductor.

6. In combination: a section of coaxial microwave transmission line having concentric inner and outer conductors; a cartridge type crystal concentrically disposed within said outer conductor and serially connected with said inner conductor; said transmission line having a first portion on the radio frequency side of said crystal having a first characteristic impedance and second portion adjacent said crystal having a second characteristic impedance higher than said first characteristic impedance; an iris capacitively coupling the radio frequency side of said crystal to said outer conductor; and a flat spiral conductor surrounding said inner conductor having its inner end connected to said inner conductor on said radio frequency side of said crystal and having its outer end connected to said outer conductor thereby providing a high radio frequency impedance return path for rectified current passed by said crystal.

7. In combination: a section of coaxial microwave transmission line having concentric inner and outer conductors; a cartridge type crystal concentrically disposed within said outer conductor and serially connected with said inner conductor; said transmission line having a first portion on the radio frequency side of said crystal having a first characteristic impedance and a second portion adjacent said crystal having a second characteristic impedance higher than said first characteristic impedance; an iris capacitively coupling the radio frequency side of

said crystal to said outer conductor; an annular member of insulating material surrounding said inner conductor on the radio frequency side of said crystal and extending outwardly to said outer conductor; and a spiral conductor supported on said annular insulating member surrounding said inner conductor with its inner end contacting the same and its outer end contacting said outer conductor thereby providing a high radio frequency impedance return path for rectified current passed by said crystal.

8. In combination: a section of coaxial microwave transmission line having concentric inner and outer conductors; a generally tubular crystal cartridge concentrically disposed within said outer conductor and having its terminals serially connected with said inner conductor; said outer conductor having a step formed in its inner surface in general alignment with the radio frequency terminal of said crystal cartridge, said step dividing said outer conductor into a first portion extending on the radio frequency side of crystal cartridge with a first inside diameter thereby providing a first characteristic impedance and a second portion extending in the opposite direction axially coextensive with said crystal from said first portion with a second inside diameter greater than said first inside diameter thereby providing a second characteristic impedance greater than said first characteristic impedance; an annular member of insulating material removably positioned within said outer conductor surrounding the portion of said inner conductor connected to said radio frequency terminal of said crystal cartridge and extending outwardly to said first portion of said outer conductor; and a spiral conductor supported on one sde of said annular insulating member surrounding said inner conductor portion with its inner end contacting the same and its outer end contacting said outer conductor thereby providing a high radio frequency impedance return path for rectified current passed by said crystal cartridge.

9. In combination: a section of coaxial microwave transmission line having concentric inner and outer conductors; a cartridge type crystal concentrically disposed within said outer conductor and serially connected with said inner conductor; said transmission line having a first portion on the radio frequency side of said crystal having a first characteristic impedance and a second portion adjacent said crystal having a second characteristic impedance higher than said first characteristic impedance; said second portion being axially coextensive with said crystal; capacitor means between said outer conductor and said inner conductor on the radio frequency side of said crystal; and a flat spiral conductor surrounding said inner conductor having its inner end connected to said inner conductor on said radio frequency side of said crystal and having its outer end connected to said outer conductor thereby providing a high radio frequency impedance return path for rectified current passed by said crystal.

10. In combination: a section of coaxial microwave transmission line having concentric inner and outer conductors; a generally tubular crystal cartridge concentrically disposed within said outer conductor and having its terminals serially connected with said inner conductor; said outer conductor having a step formed in its inner surface in general alignment with the radio frequency terminal of said crystal cartridge, said step dividing said outer conductor into a first portion extending on the radio frequency side of crystal cartridge with a first inside diameter thereby providing a first characteristic impedance and a second portion extending in the opposite direction from said first portion with a second inside diameter greater than said first inside diameter thereby providing a second characteristic impedance greater than said first characteristic impedance; an annular conductive member extending inwardly from said second portion of said outer conductor adjacent said step and having its center opening surrounding and spaced from said radio frequency terminal of said crystal cartridge thereby forming a capacitive iris therewith; an annular member of insulating material removably positioned within said outer conductor surrounding the portion of said inner conductor connected to said radio frequency terminal of said crystal cartridge and extending outwardly to said first portion of said outer conductor; and a spiral conductor suported on one side of said annular insulating member surrounding said inner conductor portion with its inner end contacting the same and its outer end contacting said outer conductor thereby providing a high radio frequency impedance return path for rectified current passed by said crystal cartridge.

11. In combination: a section of coaxial microwave transmission line having concentric inner and outer conductors; a generally tubular crystal cartridge concentrically disposed within said outer conductor and having its terminals serially connected with said inner conductor; said outer conductor having a step formed in its inner surface in general alignment with the radio frequency terminal of said crystal cartridge, said step dividing said outer conductor into a first portion extending on the radio frequency side of crystal cartridge with a first inside diameter thereby providing a first characteristic impedance and a second portion extending in the opposite direction from said first portion with a second inside diameter greater than said first inside diameter thereby providing a second characteristic impedance greater than said first characteristic impedance; an annular conductive member extending inwardly from said second portion of said outer conductor adjacent said step and having its center opening surrounding and spaced from said radio frequency terminal of said crystal cartridge thereby forming a capacitive iris therewith; an annular member of insulating material removably positioned within said outer conductor surrounding the portion of said inner conductor connected to said radio frequency terminal of said crystal cartridge and extending outwardly to said first portion of said outer conductor; a spiral conductor supported on one side of said annular insulating member surrounding said inner conductor portion with its inner end contacting the same and its outer end contacting to said outer conductor thereby providing a high radio frequency impedance return path for rectified current passed by said crystal cartridge; another annular conductive member extending inwardly from said second portion of said outer conductor and embracing the other terminal of said crystal cartridge; and an annular member formed of insulating material spacing said other crystal cartridge terminal from the opening in said other annular conductive member thereby forming a capacitive connection therewith.

References Cited in the file of this patent

UNITED STATES PATENTS

2,498,335	Hunt	Feb. 21, 1950
2,527,979	Woodyard	Oct. 31, 1950
2,810,829	Schrock	Oct. 22, 1957
2,816,270	Lewis	Dec. 10, 1957
2,840,710	Levy	June 24, 1958