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Fletcher et al.

[11] **3,902,143**

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[54] **REFRIGERATED COAXIAL COUPLING**

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[51] **Int. Cl.**[2]..... **H01P 1/16; H01P 5/08**

[58] **Field of Search**..... 333/96 R, 97 R, 99 R, 99 S, 333/83 T, 84 R, 83 R, 98 P, 21 R, 21 A; 174/15 C; 331/69

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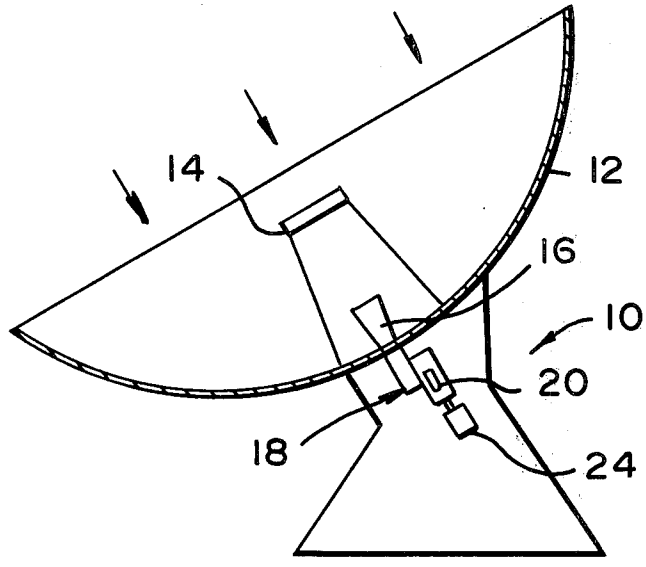
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[57] **ABSTRACT**

A transmission line for improving the sensitivity of a maser or other microwave processing equipment by using a cooled coaxial line for coupling a waveguide to a refrigerated maser, wherein the central coaxial conductor has an outer end projecting into the waveguide and covered by a quartz dome. The space between the central and outer conductors of the coaxial line is evacuated to minimize heat transfer, the central coaxial conductor is supported by the outer conductor at only its inner end which is refrigerated to less than 5° Kelvin, and the central coaxial conductor is a short solid copper rod to maintain even the outer end at a low temperature.

7 Claims, 3 Drawing Figures



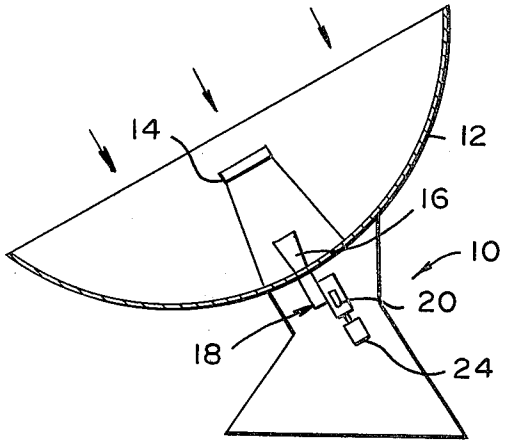

14
12
16
10
20
18
24

FIG. 1

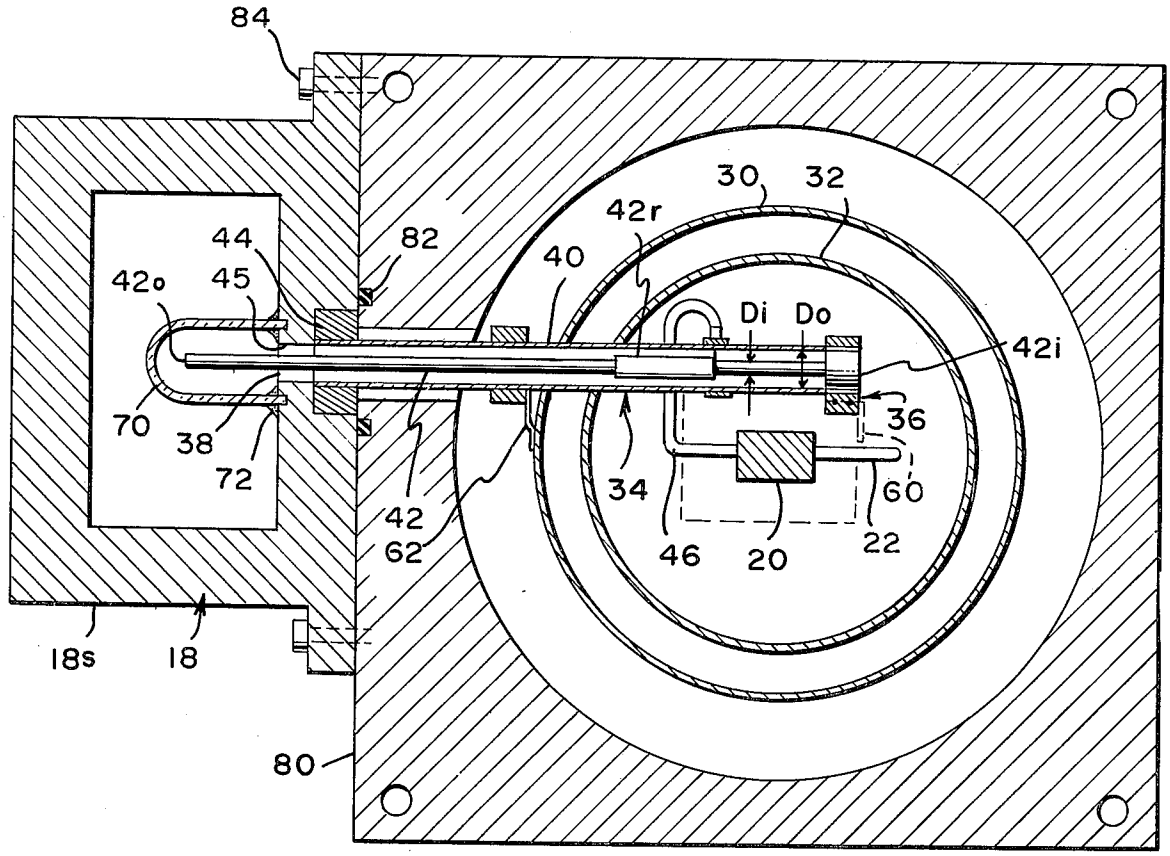
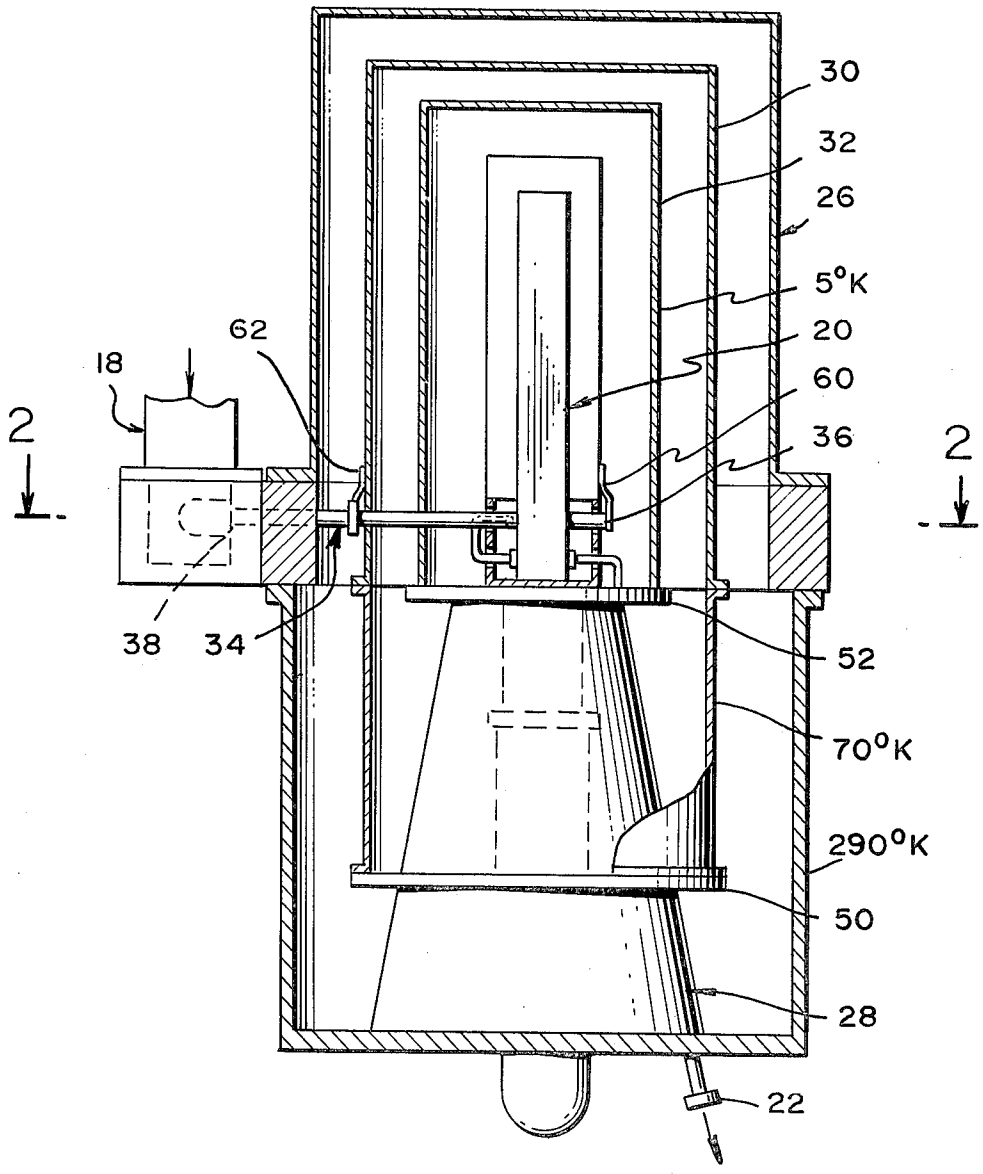

84
30
32
42r
44
82
40
42o
45
Di
Do
42i
70
38
72
36
34
60
42
62
46
20
22
18s
18
80

FIG. 2

FIG. 3



REFRIGERATED COAXIAL COUPLING

ORIGIN OF INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U. S. C. 2457).

BACKGROUND OF THE INVENTION

This invention relates to an input signal transmission line for connecting a waveguide to a refrigerated maser or other signal processing apparatus.

Antennas utilized in space communications may include a large dish structure that reflects microwave signals into a waveguide, maser refrigerated to a temperature of less than 5°K(Kelvin) for amplifying the signals, and an input transmission line that connects the waveguide to the maser. For microwaves at moderate to large wavelengths, a coaxial line is typically utilized to couple the waveguide to the maser in order to minimize the size and weight of the refrigerating apparatus and shielding. However, a coaxial line can introduce appreciable noise if it is at a temperature considerably above absolute zero, with most of the noise being generated at the central, or inner conductor of the coaxial line where current densities are greatest. In the prior art, the inner end of the central coaxial conductor was typically cooled to less than 5°K, and a long coaxial line was utilized to minimize heat transfer from the outer, room temperature end of the line which lies within the waveguide, to the refrigerated inner end. Also, the central conductor was typically constructed as a stainless steel tube to minimize heat transfer therealong but with a coating of copper to carry the microwave currents. A dielectric spacer had to be employed along the coaxial line to support the long central conductor and as a seal to prevent air from passing to the cryogenically cooled inner end. While this coaxial line arrangement allows part of the central coaxial conductor to be cooled to minimize noise, appreciable noise is produced near the outer end which is at the ambient temperature of nearly 290°K.

SUMMARY OF THE INVENTION

In accordance with one embodiment of the present invention, a microwave signal processing apparatus is provided which includes a coaxial line for coupling a waveguide at room temperature to a maser at a temperature of less than 5°Kelvin, wherein the coaxial line arrangement is constructed to minimize the temperature of the central and outer coaxial conductors to minimize noise. The outer end of the central coaxial conductor, which projects into the waveguide, is surrounded by a quartz dome which is sealed around its edge to maintain a vacuum along the entire length of the coaxial line. The central coaxial conductor is supported by the outer conductor only at its inner end which is thermally coupled to the coldest refrigeration stage of the refrigerator apparatus to maintain the inner end below 5°K. The inner coaxial conductor is constructed of a solid copper rod to provide good heat conductivity, so that a temperature below 5°K is maintained throughout the entire length of the inner coaxial conductor.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention will best be understood from the following description when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified sectional side view of a space communication receiving station which includes the microwave processing apparatus of the invention;

FIG. 2 is a sectional top view of the microwave processing apparatus of the invention; and

FIG. 3 is a sectional side view of the processing apparatus of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates a typical receiving station 10 for spacecraft communications, including a large dish antenna 12 where microwaves are reflected to a secondary reflector 14 and to a horn 16 that converges into a waveguide 18. Microwaves in the waveguide 18 are amplified in a maser 20 which delivers amplified signals to further processing apparatus 24. As illustrated in FIGS. 2 and 3, the maser 20 is contained within an evacuated housing 26 which holds refrigerating apparatus 28 that cools the maser 20 to less than 5°K(Kelvin). The volume within the housing 26 is evacuated to minimize conductive or convective heat transfer, and a pair of radiation shields 30, 32 within the housing minimize radiation heat transfer to the maser.

Microwave signals in the waveguide 18 are carried to the maser 20 by a coaxial line 34 which has an inner end 36 lying deep in the housing and within the radiation shield 32, and an outer end 38 which extends to the waveguide 18. As best shown in FIG. 2, the coaxial line includes an outer coaxial conductor 40 and a central or inner coaxial conductor 42 which lies within the outer conductor. The central conductor 42 is a solid rod of highly conductive material such as copper, with an outer end 42*o* lying within a waveguide section 18s for receiving microwave signals. The central coaxial conductor has an inner end 42i which is fixed both thermally and electrically to the inner end of the outer coaxial conductor with a clamp 36. The outer conductor 40 is a thin tube of stainless steel with a highly conductive inner coating such as copper. A film of gold may lie on all of the copper surfaces to prevent corrosion. The outer end of the outer conductor is fastened to a support flange 44 which rests in a groove of the waveguide section 18s which is aligned with a hole 45 in the waveguide section. The wall of the hole 45 serves as part of the outer coaxial conductor at its outer end 38. The maser 20 is connected to the coaxial line 34 by an additional coaxial line 46. The entire coaxial line assembly (40, 36, 42) is mechanically supported at the room temperature waveguide interface at the support flange 44, so that excellent position stability between the coaxial central conductor and the waveguide is achieved. This assures maintenance of a constant impedance transformation.

The coaxial line 34 is utilized to carry microwave signals from the waveguide 18 to the maser 20 because the coaxial line has a much smaller diameter than that of a waveguide for moderate to low microwave frequencies, and the small size minimizes the size of the refrigeration and heat shielding apparatus around the maser. However, a coaxial line can introduce appreciable noise if its temperature is significantly above absolute zero. The central coaxial conductor 42 is the pre-

dominant source of noise because of its small outer surface area as compared to the internal surface area of the outer conductor **40.** The outer conductor **40** is a continuous tubing to prevent signal losses to or noise pick-up from the space in the vacuum housing **26** surrounding the coaxial line. That is, if a gap were left in the outer conductor **40,** noise from the higher temperature surroundings might enter through such a gap.

The refrigerator **28** (FIG. 3) has a first stage connected to a plate **50** which is at a temperature such as **70°K,** which is considerably below room or ambient temperature (typically **290°K**) of the housing **26** and of the waveguide **18.** The refrigerator has a final stage connected to a flange **52,** which is at a temperature of **4.5°K,** which, of course, is close to absolute zero. The refrigerator typically also has at least one intermediate stage between the first and final stages. The radiation shield **30** which is connected to the first stage heat station **50** is maintained at about the same temperature of **70°K** as the station **50,** while the radiation shield **32** is maintained at approximately the **4.5°K** temperature of the flange **52.**

The outer coaxial conductor **40** (FIG. 2) is cooled by a pair of flexible straps **60, 62,** with the strap **60** connected to a **4.5°K** station while the strap **62** is connected to the outer radiation shield **30** which is at about **70°K.** There is a large temperature gradient along a short length of the outer conductor, but only a small amount of noise is added even along the outer end thereof which is at room temperature, because of the large internal area of the outer conductor where microwave currents pass.

In accordance with the present invention, the central conductor **42** is maintained at nearly absolute zero all along its length to minimize the generation of noise therealong. The outer end **42***o* of the central coaxial conductor is enclosed by a dielectric cover or dome **70** of an impervious and low-loss material such as quartz, with the bottom of the cover sealed at **72** in a groove in the waveguide section **18***s* to form a vacuum seal. This allows the region within the coaxial conductor, between the central and outer conductors thereof, to be maintained at a high vacuum so that there is substantially no conductive heat transference therebetween. The central conductor **42** is mechanically supported by the outer conductor only at its inner end **42***i* where it is also connected to the flexible strap **60** at the **4.5°K** heat station. Thus, by supporting the central conductor **42** at only the inner end where it is thermally connected to a refrigerator station at nearly absolute zero, and by maintaining a vacuum around the inner conductor all along its length, the central conductor can be maintained at nearly absolute zero along its entire length.

One source of slight heating of the central conductor is at its outer end **42***o* where radiation from the waveguide and quartz cover, which are at room temperature, can pass to the inner coaxial conductor. In order to minimize temperature gradients along the central conductor and maintain a temperature of less than **5°K** at the outer end of the conductor **42,** the conductor **42** is constructed of a solid rod of highly heat conductive material such as copper. This central coaxial conductor construction may be compared with previous constructions for maser input lines, wherein the central conductor was formed from a thin tube of stainless steel with a thin layer of copper or other highly conductive material on its surface. The outer end of the stainless steel tube was terminated in the waveguide at room temperature. The stainless steel tube, which has a relatively low heat conductivity, was therefore useful to minimize the heat load on the refrigerator. In the coaxial line of the present invention, however, heat transference to the outer end of the central coaxial conductor is minimized so that there is only a small amount of heat transferred to it. Therefore the central conductor can be constructed to maximize heat conductivity so as to maintain its outer end at nearly absolute zero.

The use of a solid rod for the central coaxial conductor **42** provides sufficient strength to enable support of the central conductor only at the inner end **42***i.* The central conductor is a rod of uniform diameter along its length except at an enlarged region **42***r* in front of the connection point to the maser for providing an impedance transformation. The diameter D_i is preferably **28** percent of the inner diameter D_o of the outer coaxial conductor, in order to provide a transmission line characteristic impedance of **77** ohms which provides the lowest loss and therefore the least noise. The impedance transformation at **42***r* converts to a **50** ohm output to match a typical line **46** leading to the maser. If desired, a dielectric ring can be utilized to support the central conductor on the outer conductor without producing a heat transference, so long as any such support lies at or within the inner radiation shield **32.** Such a support should not lie outside the radiation shield **32** where the outer conductor **40** experiences an increase in temperature, since any such support would transfer considerable heat and raise the temperature of the inner conductor.

The coaxial coupling is constructed to facilitate field repairs, wherein the input waveguide **18** including the section **18***s* thereof may have to be removed from an adaptor plate **80** of the housing. An elastomeric sealing washer in the form of an O-ring vacuum seal **82** lies in a groove of the adapter plate **80** to form a vacuum seal around the coaxial line **34.** The waveguide can be removed by removing fasteners **84** that hold the waveguide section **84***s* to the adapter plate **80** and then pulling the waveguide section off. The support flange **44** which lies in a groove of the waveguide section, is fastened to the outer end of the outer coaxial conductor **40** and remains with it. The dome **70** is fastened to the waveguide section **18s** and remains with the waveguide. When the waveguide section **18s** is refastened in place, a vacuum seal is automatically formed, and pumping out of the vacuum within the housing **26** can proceed.

Thus, the invention provides a coaxial coupling between a room temperature waveguide and a cryogenically cooled maser or other microwave signal amplifying apparatus, which maintains all of the central coaxial conductor at less than **5°Kelvin** to thereby minimize noise. This is accomplished by providing a dielectric cover over the outer end of the central coaxial conductor within the waveguide and maintaining a vacuum within the cover and coaxial line. The central coaxial conductor is constructed to have a high heat conductivity all along its length, and its inner end is thermally connected to a refrigerated station which is below **5°Kelvin** to maintain all of the inner conductor at a low temperature. Excellent mechanical stability between the waveguide and coaxial line is achieved by using an outer tubular conductor which is supported at the room temperature interface and thermally connected to the **70°and 4.5°** Kelvin refrigeration stations with flexible

straps. The stability between the waveguide and central coaxial conductor results in a constant impedance transformation from the waveguide to the coaxial line. This coaxial signal transmission line arrangement provides a transfer of microwave signals from a room temperature waveguide to a refrigerated maser with a minimum addition of noise, a minimum loss of signal power, and a minimum addition of heat to the refrigeration apparatus.

A maser operating at 2,295MHz using the construction of the present invention described above was measured to have an equivalent input noise temperature of 2.1°Kelvin at the waveguide connection which interfaces with the antenna feedhorn. Prior art masers of the same frequency range were measured to have equivalent noise temperatures of 4.3°Kelvin or more. The improved coaxial line of the present invention is responsible for at least 1.7°K of the 2.2°K measured improvement. Because reduced noise increases the sensitivity of a receiving system, the invention was used to receive high data rate television pictures from the vicinity of the planet Mercury during the Mariner 10 mission. A lower data rate and fewer pictures would have been sent and received if the present invention had not been utilized.

Although particular embodiments of the invention have been described and illustrated herein, it is recognized that modifications and equivalents may readily occur to those skilled in the art and consequently, it is intended that the claims be interpreted to cover such modifications and equivalents.

What is claimed is:

1. Microwave processing apparatus comprising:
walls defining a housing;
amplifying means disposed in said housing;
a waveguide extending to said housing, said waveguide having walls with a hole;
a coaxial line extending from said amplifier means to said waveguide at said hole thereof;
a refrigerator coupled to said coaxial line to cool it;
said coaxial line including a tubular outer coaxial conductor electrically coupled to the walls of said waveguide, and an inner coaxial conductor with an inner end coupled to said amplifier means and an outer end projecting through said hole in said waveguide; and
a cover of dielectric material disposed in said waveguide over said outer end of said central conductor and sealing the outer end of coaxial line around said hole;
the space between said central and outer conductors being evacuated to form a vacuum, and said refrigerator being thermally coupled to said inner end of said coaxial conductor.

2. The apparatus described in claim 1 wherein:
said inner conductor of said coaxial line is constructed of a substantially solid rod of highly heat-conductive material having a heat conductivity at least as great as that of copper, whereby to conduct heat from the outer end of the inner coaxial conductor to the refrigerator so that even the outer end of the conductor is maintained at a low temperature.

3. The apparatus described in claim 1 wherein:
said inner coaxial conductor is supported at only said inner end thereof.

4. The apparatus described in claim 1 wherein:
the inside of said housing is evacuated, said cover is sealingly attached to said waveguide to form a vacuum seal around the end of said inner coaxial conductor, said waveguide is connected to said housing by fasteners that can be readily removed and attached in the field, and including an elastomeric sealing washer (82) disposed between said waveguide and housing to form a vacuum seal between them.

5. Microwave processing apparatus comprising:
a waveguide;
a vacuum housing;
at least one radiation shield within said housing for minimizing heat transfer by radiation;
a coaxial line having an inner end within said radiation shield and an outer end outside said shield, said line having a central coaxial conductor extending through said housing and the wall of said waveguide into said waveguide, said coaxial line also having a continuous outer coaxial conductor surrounding said central coaxial conductor;
a dielectric cover disposed within said waveguide over the outer end of said central coaxial conductor;
means forming a vacuum between said cover and said outer coaxial conductor, to maintain a vacuum in said coaxial line;
a maser within said radiation shield;
means for coupling the inner end of said coaxial line to said maser; and
refrigerator means having a first stage heat station coupled to said radiation shield and having a final stage heat station which maintains a temperature less than said first stage coupled to said inner end of said coaxial line at a location within said radiation shield.

6. The apparatus described in claim 5 wherein:
said central coaxial conductor is constructed of a solid rod of material at least about as heat-conductive as copper, and said central coaxial conductor is supported only at its inner end by the outer coaxial conductor.

7. The apparatus described in claim 5 wherein:
said outer coaxial conductor is firmly supported on said waveguide, and including flexible straps of heat conductive material coupling locations along said outer coaxial conductor to said heat stations of said refrigerator means.

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