Oct. 20, 1970

C. C. DAILEY

3,535,543

MICROWAVE POWER RECEIVING ANTENNA

Filed May 1, 1969

3 Sheets-Sheet 1

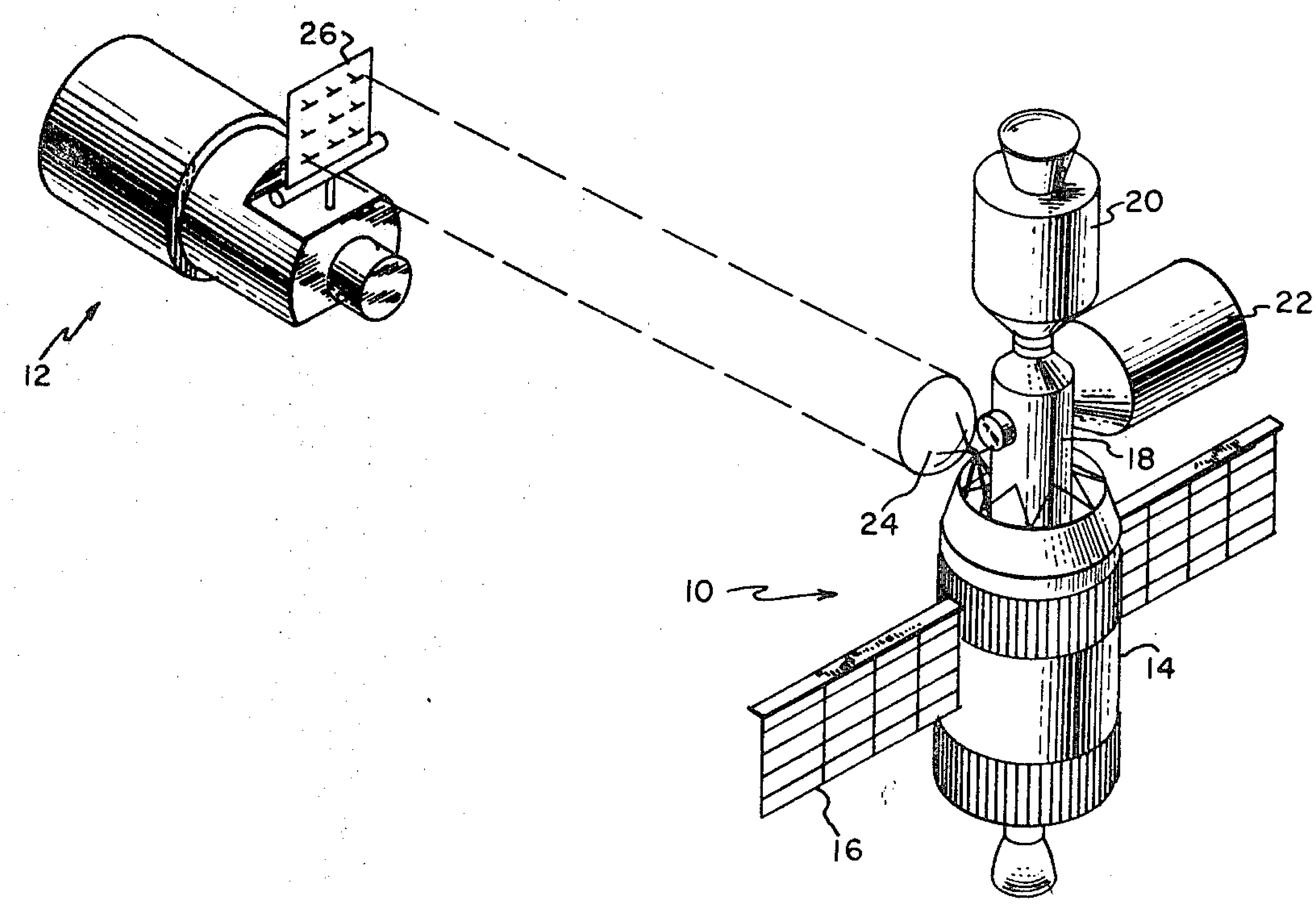

FIG. 1

INVENTOR
CARROLL C. DAILEY

BY [signatures]
ATTORNEYS

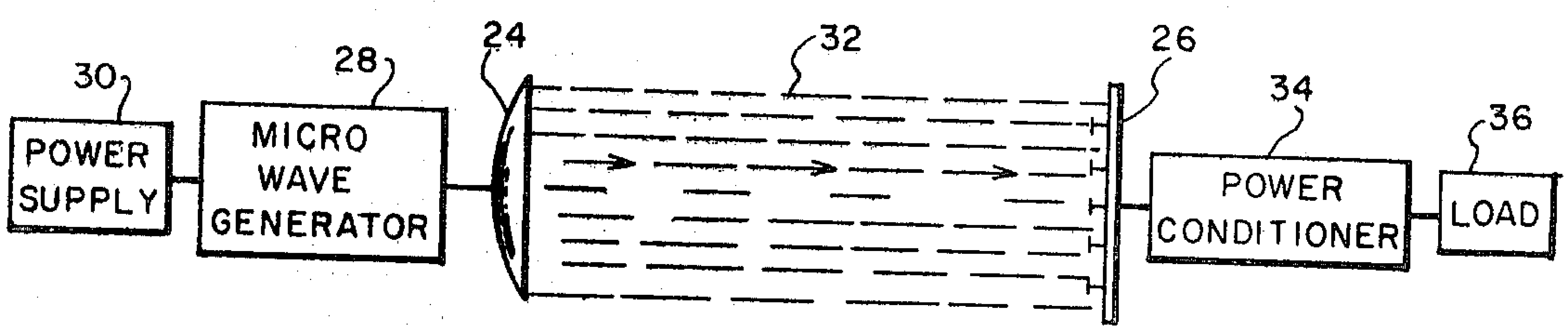

FIG. 2

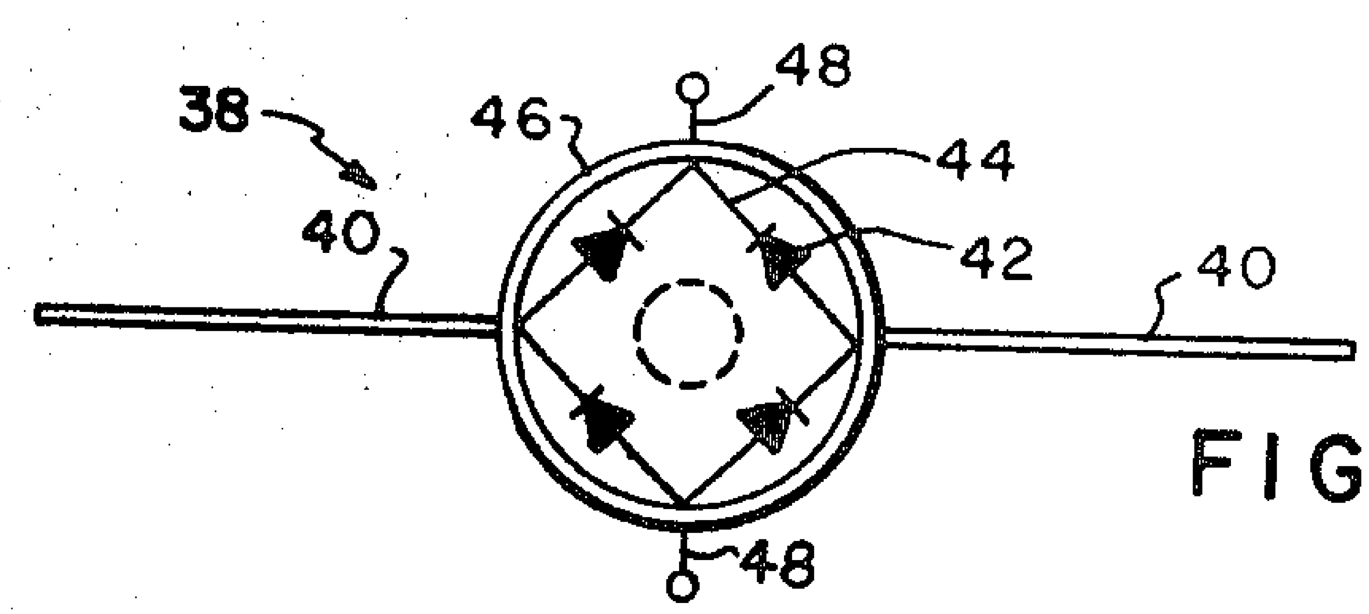

FIG. 3

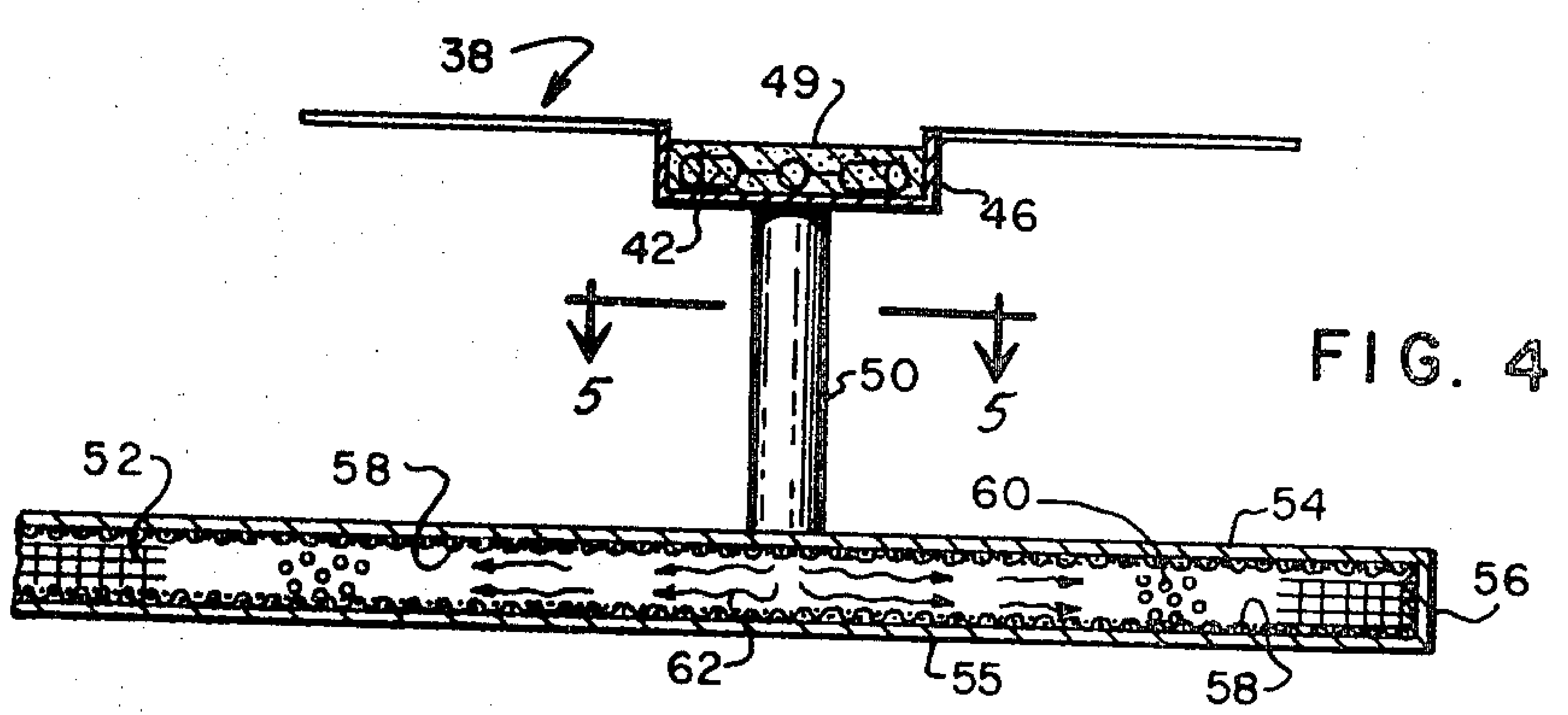

FIG. 4

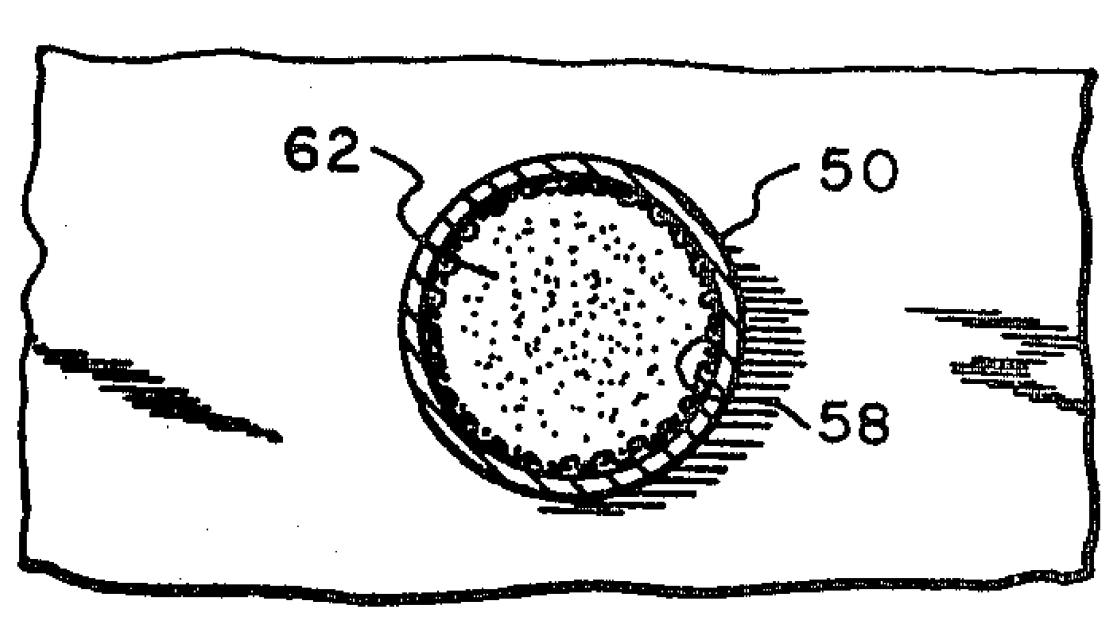

FIG. 5

INVENTOR
CARROLL C. DAILEY

BY George J. Porter
ATTORNEYS

Oct. 20, 1970 C. C. DAILEY 3,535,543

MICROWAVE POWER RECEIVING ANTENNA

Filed May 1, 1969

3 Sheets-Sheet 3

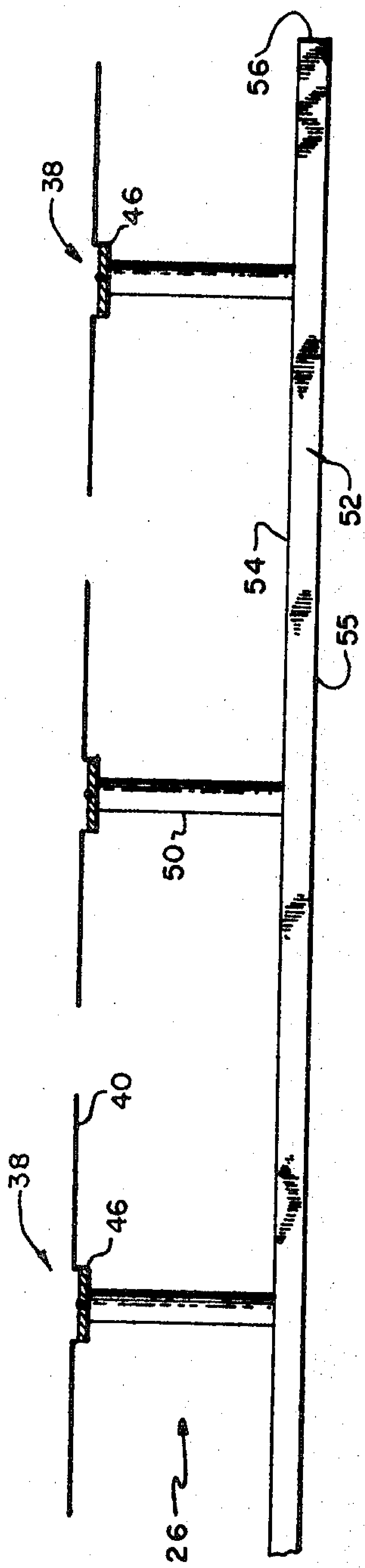

FIG. 6

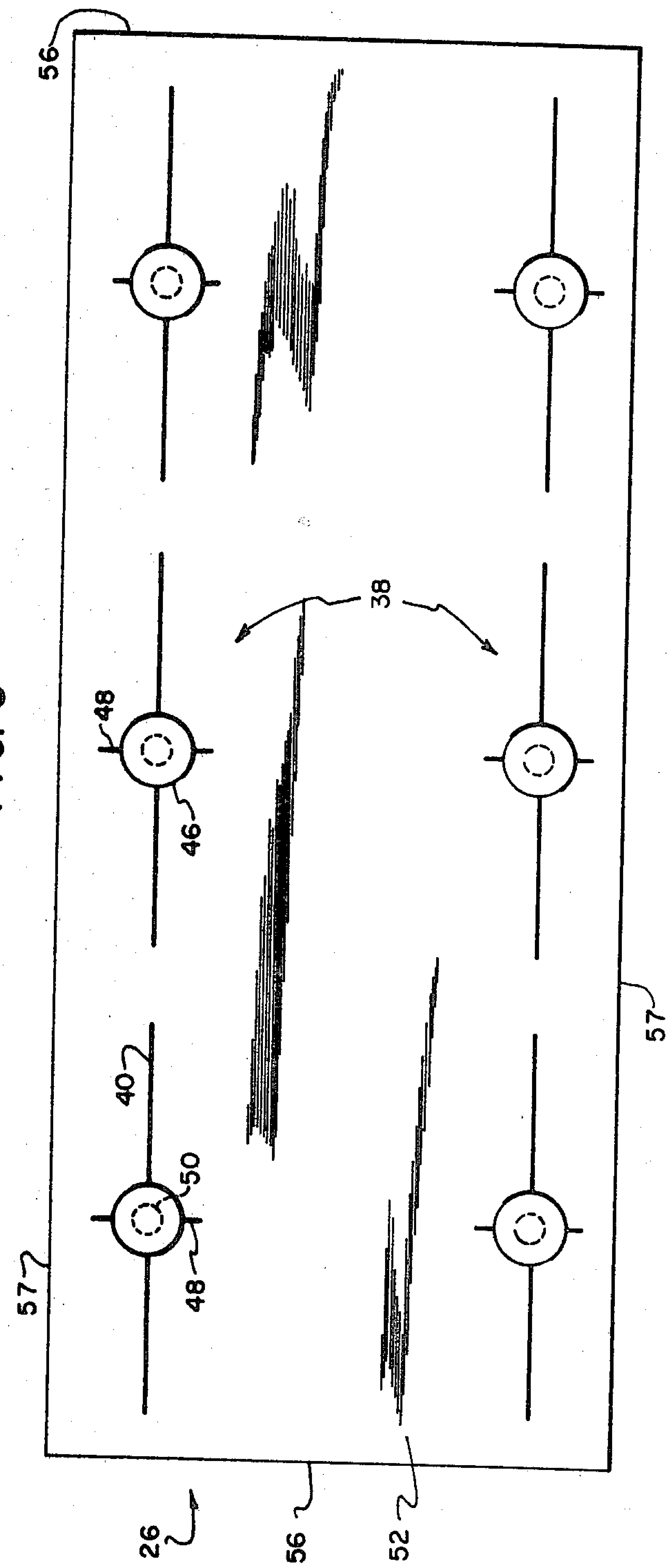

FIG. 7

INVENTOR
CARROLL C. DAILEY

BY George J. Porter
ATTORNEYS

United States Patent Office

3,535,543
Patented Oct. 20, 1970

3,535,543

MICROWAVE POWER RECEIVING ANTENNA

Carroll C. Dailey, Huntsville, Ala., assignor to the United States of America as represented by the Administrator of the National Aeronautics and Space Administration

Filed May 1, 1969, Ser. No. 820,965
Int. Cl. H02j *1/00*
U.S. Cl. 307—149 **6 Claims**

ABSTRACT OF THE DISCLOSURE

A microwave power receiving antenna array having a solid-state rectifier circuit at the center of each of a plurality of dipole antennas for conversion of the high-frequency energy to direct current. The device effectively and efficiently solves the problem of heat dissipation from the diode rectifier enclosure by construction of the dipole supporting posts, the antenna reflecter and the dipole elements as heat pipe devices. Each supporting post and the antenna reflector may either communicate for greater efficiency in dissipating heat or be physically separated to simplify fabrication.

ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government and may be manufactured or used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to power receiving antennas and more particularly to a rectifying dipole antenna array having a highly efficient structure for dissipation of heat from the rectifying circuit.

Description of the prior art

One of the comparatively recent modes of electrical power transmission is power transfer by microwaves using frequencies as high as about 30 gigahertz. One attractive use of this type of power transmission is for powering helicopters or other types of aircraft from a remote location. Another use which appears attractive is transmission of power from a central manner space station, which can service a number of small independent subsatellites or experiment modules located distances as much as several kilometers away. Batteries in a subsatellite can be recharged with energy generated in the main space station, thus precluding the need for solar arrays or extra batteries on the subsatellite, increasing its versatility, and prolonging its useful life.

In the power receiving antenna for a microwave power transmission system, a rectifying circuit may be used to convert the high frequency energy to direct current. The diodes which transform the high frequency energy to DC are usually quite efficient (approximately 70 to 90 percent). However, there is some loss of energy which appears as heat. This heat raises the temperature of the diodes. Also, the diodes and the antenna or antenna array are subject to the heating of the sun's rays. These heating effects have the inherent disadvantage of limiting the amount of electrical power that can be handled by the array because of the temperature limits of the diodes. For diodes of interest in space applications, this limit typically occurs at about 120° centigrade, although specific applications may show limits somewhat higher or lower.

In order to keep the diode temperature down, it is necessary to radiate heat to space. The area of the radiating surface available and the coatings applied to the surface determine how much heat can be radiated at a specific temperature. In the case of antenna dipoles the radiating area is small, since the conductors are narrow and the dipoles are also very small.

SUMMARY OF THE INVENTION

Accordingly, it is an object of this invention to provide an improved microwave receiving antenna.

Still another object of this invention is to provide a microwave receiving antenna having the capability of efficient dissipation of heat from its rectifier circuits.

Yet another object of this invention is to provide a more efficient microwave receiving antenna by modifying conventional elements of antenna structure so as to better radiate the heat from the antenna's rectifier circuit.

These and other objects are accomplished in the present invention which provides at least one pair of dipole antenna elements supported by an enclosure containing a rectifying circuit comprising a plurality of diodes. Each enclosure and its corresponding pair of dipoles is mounted on a heat conducting support post, which in turn is mounted on a large antenna reflector.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood by the following detailed description when taken together with the accompanying drawings in which:

FIG. 1 is an isometric view of an orbiting space laboratory transmitting electrical power to a subsatellite.

FIG. 2 is a block diagram of a microwave power system capable of utilizing the present invention.

FIG. 3 is a plan view of a dipole having a bridge rectifier at its center, illustrating part of one embodiment of the present invention.

FIG. 4 is a side view of part of a microwave receiving antenna, which illustrates one embodiment of the present invention.

FIG. 5 is a horizontal sectional view of the support post taken along line 5—5 of FIG. 4 and showing the inner construction of the heat pipe support post.

FIG. 6 is a side view of the microwave power receiving antenna array showing one row of dipoles.

FIG. 7 is a plan view of one embodiment of the microwave power receiving antenna array, showing two rows of three dipoles mounted on a reflector.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With continued reference to the accompanying figures wherein like numerals designate similar parts throughout the various views and with initial attention directed to FIG. 1 there is illustrated an orbital space laboratory, designated generally by numeral **10**, transmitting electrical power by microwaves to a subsatellite, designated generally by numeral **12**. Laboratory **10** includes a spent rocket stage **14** having solar panels **16**, docking adapter **18** and command modules **20** and **22**. Solar panels **16** may be replaced by a nuclear power source in other versions of laboratory **10**.

Referring now to FIG. 2, a microwave power system which includes the present invention is shown in block diagram form. Electrical power in the form of microwaves is furnished by microwave power generator **28** having power supply **30**. Power transmitting antenna **24** is aimed at power receiving antenna **26** and transmits electrical power in the form of microwave beam **32** to receiving antenna **26**. Subsatellite **12** uses this power received from beam **32** to charge its batteries or fuel cells or for powering electric thrusters. The energy in beam **32** is converted from high-frequency energy (approximately 2 megahertz to 30 gigahertz) to a direct current which is fed into power conditioning equipment **34** to transform it to the actual voltages required for the load **36**.

FIG. 3 shows a self-supporting, single, half-wave, Hertz antenna, designated generally by numeral **38**, having a pair of dipole antenna elements **40**. The conversion from high-frequency energy to direct current is accomplished by a plurality of diodes **42** which are connected in a bridge rectifier circuit **44** (shown in diagrammatic form). Rectifier circuit **44** is contained in dipole center enclosure **46** and is connected between the dipole elements **40** and a pair of output terminals **48**. Dipole elements **40** are securely fastened to opposite sides of enclosure **46**.

FIG. 4 shows a single, half-wave dipole antenna **38** mounted on enclosure **46**. Enclosure **46** is shown in vertical section so that diodes **42** may be seen, contained in potting compound **49**. Enclosure **46** is mounted on support post **50** which is in turn mounted on an antenna reflector **52**. Support post **50** is a hollow pipe which is closed at its upper end where it is fastened to enclosure **46** and open at its lower end where it is fastened to antenna reflector **52**. Reflector **52** comprises a pair of metal walls **54** and **55**, a pair of ends **56**, and a pair of sides **57** (see FIG. 7) all of which make reflector **52** a closed container. However, the cavity of reflector **52** communicates with the lower end of support post **50**, as described above.

Both support post **50** and antenna reflector **52** utilize known principles of operation of a heat pipe. As may be seen in both FIG. 4 and the horizontal sectional view of the support post shown in FIG. 5, all the interior surfaces of both support post **50** and reflector **52** are covered with a wicking material **58**, which may be screen wire or a similar material. The communicating space enclosed by poth the support post **50** and the antenna reflector **52** together contains a heat transfer fluid **60**, which may be water, lithium or a number of other substances which are easily vaporized.

FIGS. 6 and 7 are side and plan views, respectively, of a microwave power receiving antenna **26** having a plurality of half-wave dipole antennas 38. Each dipole **38** is supported by a corresponding dipole center enclosure **46** and support post **50**. All dipoles **38** are mounted on one antenna reflector **52**, so as to provide a combined broadside and collinear antenna array. Each support post **50** communicates with the antenna reflector **52** in a manner already described for FIG. 4 above. The internal construction of each support post **50** and the antenna reflector **52**, including wicking material **58** and the presence of heat transfer fluid **60**, is also as described for FIG. 4.

One cycle of operation of the microwave power receiving antenna **26** follows: Microwave power beam **32** is received on the dipole elements **40** of half-wave antenna **38**. Bridge rectifier circuit **44** comprising diodes **42** rectifies the incoming high-frequency energy to convert it to direct current. Power conditioner **34** changes the form of the direct current as desired and transmits it to the load **36**. Heat developed within enclosure **46** is absorbed by the top end of support post **50**. Heat transfer fluid **60** absorbs heat from the end of support post **50** and is vaporized. The vapor **62** then moves under vapor pressure down the support post **50** and passes into the inner portion of antenna reflector **52**. When the vapor **60** reaches a comparatively "cool spot" on the surface of antenna reflector **52** (which would theoretically be midway between the "hot spots" caused by the heat input from the support post **50** or as far as possible from a support post **50**), the vapor **62** condenses back to fluid **60** and forms deposits on the inner sides of antenna reflector walls **54** and **55**, antenna reflector ends **56**, and antenna reflector sides **57**. The fluid **60** (condensate) then moves by means of capillary flow through the wicking material **58** back to the top of support post **50**, where it absorbs more heat and starts the cycle over. In condensing, vapor **62** gives up heat which is absorbed by walls **54** and **55**, ends **56**, and sides **57**. Thus, heat is distributed evenly to all parts of the surface of antenna reflector **52** so that reflector **52** is able to effectively dissipate this heat by radiation into space.

In an alternative arrangement of the invention the interior cavity of each support post **50** does not communicate with the interior cavity of the antenna reflector **52**. Instead, the upper sidewall **54** has no openings. In this embodiment, each support post **50** as well as the antenna reflector **52** contains its own supply of heat transfer fluid **60**, which cycles within the cavity available. Thus, heat is transferred down the support post **50** and passes by conduction through wall **54** of the antenna reflector **52**. The heat is then transferred evenly to the walls of the antenna reflector **52** where it is dissipated in the manner already described above.

In another alternative arrangement, the invention may be made with a conventional flat or concave antenna reflector **52**, with a corresponding sacrifice in the heat dissipation capability of the antenna array.

Any of the above-described arrangements of the invention may be made with still another variation in its construction. Each of the antenna dipole elements **40** is made in the form of a heat pipe having its interior walls and ends lined with a wicking material **58**. Also, each dipole element **40** is completely enclosed and contains its own supply of heat transfer fluid **60**. Fluid **60** cycles within the cavity of each dipole element **40** in a manner already described above for support post **50**, taking on heat from enclosure **46** and removing it to the outside end of each dipole **40**, where it is radiated to space.

From the foregoing it may be seen that applicant has invented a novel type of microwave power receiving antenna capable of more efficient dissipation of heat than antennas previously known. The outputs from the individual dipole antennas may be connected either in series, in parallel or in series-parallel, as desired. Also, diodes **42** may be mounted directly in the cavity of support post **50** to improve heat transfer efficiency, provided they are properly insulated electrically and the appropriate electrical connections are made through the upper end of support post **50**. This approach, although more difficult from the standpoint of fabrication, is desirable at high power levels.

Of the various embodiments described in detail above, the embodiment which has support posts which communicate with the antenna reflector and which also has heat pipe conducting dipole elements is, of course, the most efficient. The simpler embodiments, although they sacrifice efficiency which is highly desirable in the invention, do have the advantage of being cheaper and easier to manufacture.

What is claimed is:

1. A microwave power receiving antenna comprising:

(a) at least one pair of dipole antenna elements,

(b) at least one dipole center enclosure, the inside ends of each pair of said antenna elements being mounted on one said enclosure,

(c) a rectifying circuit in each said enclosure, said rectifying circuit comprising a plurality of diodes,

(d) at least one support post, each said enclosure being supported by one said support post,

(e) an antenna reflector, each said support post being mounted on said antenna reflector.

2. The microwave power receiving antenna of claim **1** wherein each said support post comprises:

(a) a cylindrical section of pipe having two closed ends,

(b) a fluid contained inside said pipe, for absorbing heat at the end of said pipe attached to said center enclosure, and discharging heat to said antenna reflector at the end of said pipe attached to said antenna reflector,

(c) a wick positioned along the inner surfaces of said cylindrical section of said pipe and said pipe ends, for returning said fluid from said end of said pipe attached to said antenna reflector to said end of said pipe attached to said diode enclosure.

3. The microwave power receiving antenna of claim **2** wherein said antenna reflector is a completely enclosed, flat, double-wall enclosure, said enclosure containing:

(a) a fluid for absorbing heat at the point of attachment of each said support post to said antenna reflector and discharging the absorbed heat to points on the surface of said antenna reflector remote from poinst of attachment of each said support post, so as to distribute the absorbed heat to the whole surface area of said antenna reflector,

(b) a wick positioned on substantially all of the inner surface area of said antenna reflector, for returning said fluid from said remote points to said point of attachment of said support post.

4. The microwave power receiving antenna of claim **3** wherein each said dipole antenna element comprises:

(a) a cylindrical section of tubing having two closed ends,

(b) a fluid contained inside said tubing, for absorbing heat at the end of said tubing attached to said center enclosure and discharging heat at the opposite end of said closed section of tubing,

(c) a wick positioned along the inner surface of said tubing for returning said fluid from said opposite end of said tubing to said end of said tubing mounted on said center enclosure.

5. The microwave power receiving antenna of claim **1** wherein:

(a) each said support post comprises an enclosed, cylindrical section of pipe,

(b) said antenna reflector comprises an enclosed, flat, double-wall enclosure, the enclosed area of each said support post communicating with the enclosed area of said antenna reflector, to form a total enclosed area including the enclosed areas of each said support post and said antenna reflector,

(c) said total enclosed area containing:

(1) a fluid for absorbing heat from said center enclosure and discharging the absorbed heat to points on the surface of said antenna reflector remote from points of attachment of each said support post, so as to distribute the absorbed heat to the whole surface area of said antenna reflector,

(2) a wick positioned on substantially all of the inner surface areas of said antenna reflector and each said support post, for returning said fluid from said remote points to said end of each said support post attached to said center enclosure.

6. The microwave power receiving antenna of claim **5** wherein each said dipole antenna element comprises:

(a) a cylindrical section of tubing having two closed ends,

(b) a fluid contained inside said tubing, for absorbing heat at the end of said tubing attached to said center enclosure and discharging heat at the opposite end of said closed section of tubing,

(c) a wick positioned along the inner surface of said tubing for returning said fluid from said opposite end of said tubing to said end of said tubing mounted on said center enclosure.

References Cited

UNITED STATES PATENTS

3,432,690 3/1969 Blume.

ROBERT K. SCHAEFER, Primary Examiner

H. J. HOHAUSER, Assistant Examiner

U.S. Cl. X.R.

174—15; 317—100; 313—105; 321—8; 310—4