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ELECTROSTATIC PLASMA MODULATOR FOR SPACE VEHICLE RE-ENTRY COMMUNICATION
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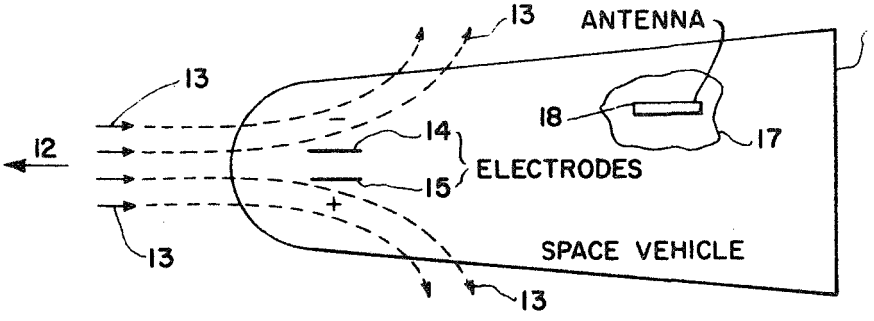

FIG. 1

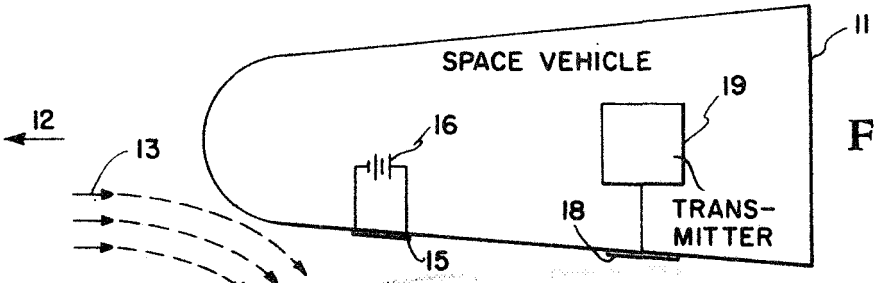

FIG. 2

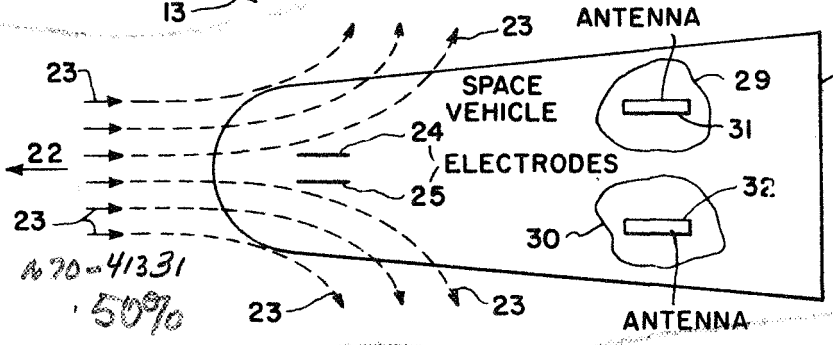

FIG. 3

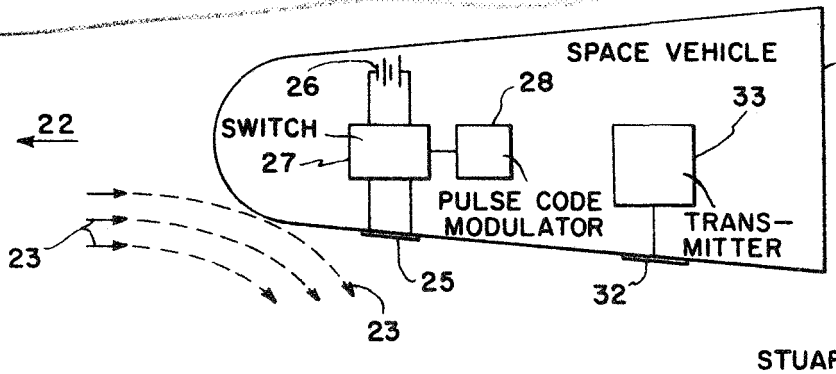

FIG. 4

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ELECTROSTATIC PLASMA MODULATOR FOR SPACE VEHICLE RE-ENTRY COMMUNICATION

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3 Claims. (Cl. 325—65)

This invention relates generally to communicating through a layer of ionized gases and more particularly concerns communicating through the layer of ionized gases formed around a space vehicle as it enters or leaves a planetary atmosphere.

Whenever a space vehicle traveling at a hypersonic speed enters or leaves a planetary atmosphere, it is surrounded by a shock-induced layer of ionized gases or plasma. If electromagnetic waves of radio frequency are directed into this layer of plasma, the free electrons in the plasma respond easily to the electromagnetic waves and in so doing collide with other gas particles. This results in dissipation of the systematic electromagnetic wave energy and loss of any information being carried by the electromagnetic waves. Consequently, radio frequency communication ordinarily cannot be maintained through the layer of plasma.

In the past there have been several schemes suggested for accomplishing radio wave communication through the layer of plasma surrounding a space vehicle while it is reentering the earth's atmosphere. Among these schemes is the scheme of selecting for use a signal frequency that will penetrate or pass through the hypersonically generated plasma. Extremely high radio wave frequencies will pass through the plasma unaltered. However, since most communicating equipment presently in use is designed for the VHF-UHF bands (30 mc. to 300 mc. and 300 mc. to 3,000 mc.), there is an equipment acquisition problem if the extremely high frequencies are used. Also, at the high frequencies there is an atmospheric absorption problem.

Other schemes suggested for accomplishing radio wave communication through the layer of plasma includes aerodynamic shaping, material injection and use of the layer of plasma as an electromagnetic radiator. However, none of these schemes satisfies all foreseeable requirements.

Plasma is composed of free electrons, positive ions, and other constituents. Since it is the free electrons in the plasma that are most responsive to electromagnetic wave energy, if the free electrons were operated upon in such a way as to divert them from a region, then information-carrying electromagnetic waves could pass through this region substantially undisturbed. It is the primary purpose of the present invention to use electrostatic means to create such a region. This is accomplished by placing charged electrostatic plates in the plasma. The negatively charged plates will repel the free electrons thereby diverting them from a certain region. An antenna is placed such that it can emit electromagnetic waves through this region; consequently, electromagnetic wave communication can be maintained through the plasma.

It is therefore an object of this invention to provide means for maintaining electromagnetic wave communication through a layer of ionized gases.

Another object of this invention is to provide means for maintaining electromagnetic wave communication through the layer of plasma formed around a space vehicle as it either enters or leaves a planetary atmosphere.

A further object of this invention is to use electrostatic means to create a region in a layer of ionized gases that is substantially devoid of free electrons whereby electromagnetic wave communciation can be maintained through the layer of ionized gases.

Other objects and advantages of this invention will further become apparent hereinafter and in the drawings in which:

FIG. 1 shows a side view of the outline of a space vehicle for the purpose of describing the theory of this invention;

FIG. 2 shows a top view of the space vehicle shown in FIG. 1;

FIG. 3 shows a side view of the outline of a space vehicle utilizing the preferred embodiment of this invention; and

FIG. 4 shows a top view of the space vehicle shown in FIG. 3.

In describing the invention illustrated in the drawings, specific terminology will be resorted to for the sake of clarity. However, it is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar purpose.

Turning now to FIG. 1 there is shown a side view of the outline of a space vehicle **11**. When space vehicle **11** is traveling in a direction indicated by arrow **12** and is either entering or leaving a planetary atmosphere, a layer of ionized gases or plasma is formed around the space vehicle. This layer of plasma is composed of free electrons and other constituents. These free electrons, relative to space vehicle **11**, travel in directions indicated by arrows **13**. Ordinarily, the direction of flow of these free electrons is affected only by the space vehicle. Consequently, there is a layer of these free electrons formed around substantially the whole surface of space vehicle **11**. Due to this layer of free electrons, electromagnetic wave communication to and from space vehicle **11** becomes practically impossible by conventional means.

This invention consists of attaching an electrode **14** and an electrode **15** to the outer skin of space vehicle **11**. Electrodes **14** and **15** are insulated from the outer skin of space vehicle **11** and are connected to a voltage source **16** shown in FIG. 2. For purposes of explanation, electrode **14** is shown charged negatively and electrode **15** is shown charged positively. Due to the negative charge on electrode **14** the paths, indicated by arrows **13**, of the free electrons are deflected thereby creating a region **17** that is substantially devoid of any free electrons. An antenna **18** is attached to space vehicle **11** within the region **17** and a conventional transmitter **19** is connected to antenna **18**. The electromagnetic waves emitted by antenna **18** will pass through the layer of plasma formed around space vehicle **11** in the region **17** thereby encountering relatively few free electrons. Therefore, any information carried by the electromagnetic waves emitted by antenna **18** will pass through the layer of plasma substantially unaltered.

The embodiment of the invention shown in FIGS. 1 and 2 is not practical since in a short time charge accumulation on electrodes **14** and **15** make them ineffective for deflection purposes. The preferred embodiment shown in FIGS. 3 and 4 overcomes this difficulty. FIG. 3 shows a side view of the outline of a space vehicle **21**. Space vehicle **21** travels in a direction indicated by arrow **22**. The directions of travel of the free electrons, in the layer of plasma formed around space vehicle **21**, relative to space vehicle **21** are shown by arrows **23**.

An electrode **24** and an electrode **25** are attached to the outer skin of space vehicle **21**. Electrodes **24** and

25 are insulated from the outer skin of space vehicle 21 and are connected to a voltage source 26. Connected between voltage source 26 and electrodes 24 and 25 is a switching device 27. The function of switching device 27 is to intermittently reverse the polarities of the voltages applied to electrodes 24 and 25. Under these conditions, two regions, 29 and 30, alternately devoid of electrons will be developed successively. That is region, 29 will be devoid of electrons while electrode 24 is charged negatively and electrode 25 is charged positively and region 30 will be devoid of electrons while electrode 24 is charged positively and electrode 25 is charged negatively. An antenna 31 is attached to the outer skin of space vehicle 21 in the region 29 and an antenna 32 is attached to the outer skin of space vehicle 21 in the region 30. A conventional transmitter 33 is connected to both antenna 31 and antenna 32. The electromagnetic waves emitted by antennas 31 and 32 will pass through the layer of plasma formed around space vehicle 21 in the regions 29 and 30, respectively.

If a sufficient time elapses between the time that the polarities of electrodes 24 and 25 are reversed and the time that the charge accumulation on the electrodes makes them ineffective for deflection purposes, then continuous communication can be maintained through the plasma. However, since this time laspe is so short as to require an impracticably high switching frequency, a different approach is taken by this invention. Information is transmitted from space vehicle 21 by supplying antennas 31 and 32 with a continuous wave energy and encoding the reversal of the electrostatic field created by electrodes 24 and 25 in the nature of a pulse code modulation. Transmitter 33 supplies antennas 31 and 32 with a continuous wave energy of a suitable frequency, e.g., 5 kmc/sec. Switching device 27 can then be used to reverse the polarity of voltage source 26 applied to electrodes 24 and 25 in accordance with a pulse modulation code. Accordingly, switching device 27 is actuated by a pulse code modulator 28. Thus, the continuous wave emission from space vehicle 21 is alternately permitted to exit, and be blocked off from the exit in response to the application and reversal of the electrostatic field applied to electrodes 24 and 25 by switching device 27 in consonance with a predetermined encoding system having a one-to-one corrsepondence with a useful symbolism.

The operation of the preferred embodiment of the invention disclosed in FIGS. 3 and 4 will now be described. Transmitter 33 is continuously supplying wave energy at a suitable frequency to antennas 31 and 32. Switching device 27 reverses the polarity of the voltage source 26 applied to electrodes 24 and 25 in accordance with information to be transmitted. Each time the polarity is reversed either region 29 or region 30 becomes deviod of electrons for a short period of time. During these short periods of time, the electromagnetic waves emitted by antennas 31 and 32 pass through the layer of plasma formed around space vehicle 21 unattenuated.

These waves can be picked up by a remote receiver and then decoded to obtain the information supplied to switching device 27.

Pluse code modulator 28 can be any well known pulse code modulator. For example, the ones supplied by ITT Laboratories. The details of switching device 27 have not been disclosed since it is obviously within the skill of one having ordinary skill in the electrical arts to design such a switch. The function of switching device 27 is to reverse the connections of voltage source 26 to electrodes 24 and 25 each time a pulse is received from pulse code modulator 28. It is also possible for switching device 27 to be a hand-operated switch. Then there would be no need for pulse code modulator 28.

It is to be understood that the form of the invention herewith shown and described is to be taken as a preferred embodiment. Various changes may be made in the shape, size, and arangement of parts. For example, equivalent elements may be substituted for those illustrated and described herein, parts may be reversed, and certain features of the invention may be utilized independently of the use of other features, all without departing from the spirit or scope of the invention as defined in the following claims.

What is claimed is:

1. Means for communicating through the layer of ionized gases formed around a space vehicle as it enters or leaves a planetary atmosphere comprising: electrostatic means mounted on said space vehicle for alternately producing two regions in said layer that are devoid of free electrons; antenna means attached to said space vehicle in said regions; and a radio transmitter means connected to said antenna means for transmitting electromagnetic waves through said regions.

2. Means in accordance with claim 1 wherein said electrostatic means comprises: two electrodes attached to the outer surface of said space vehicle; a voltage source connected across said two electrodes; and switching means for reversing the connections of said voltage source across said two electrodes.

3. Means in accordance with the claim 2 wherein said switching means reverses the connections of said voltage source across said two electrodes in accordance with a predetermined encoding system whereby useful information can be transmitted.

References Cited by the Examiner

UNITED STATES PATENTS

3,128,965	4/1964	Ziemer.	
3,176,227	3/1965	Bender	325—65
3,176,228	3/1965	Phillips et al.	325—65

FOREIGN PATENTS

635,784	4/1950	Great Britain.

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