June 30, 1970 A. MILLER 3,518,670

ARTIFICIAL ION CLOUD

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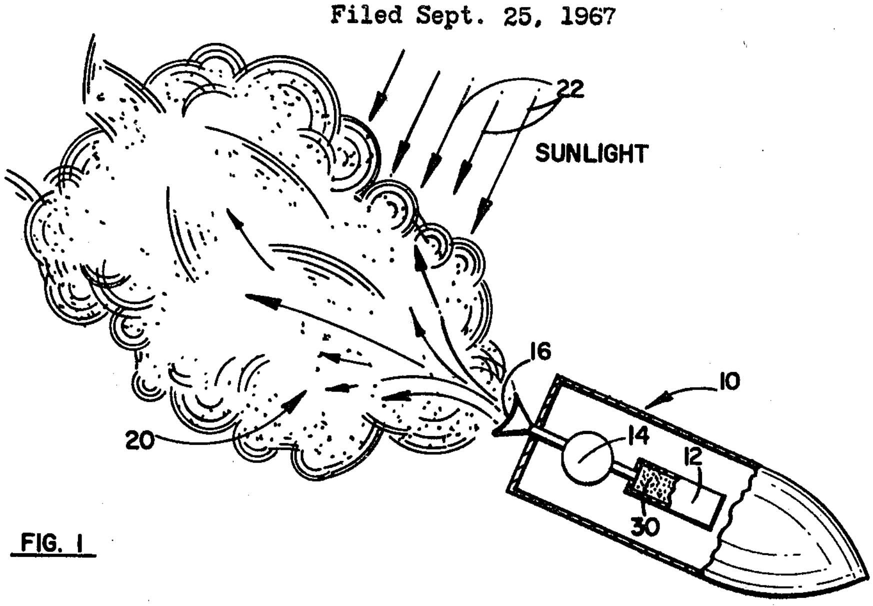

FIG. 1

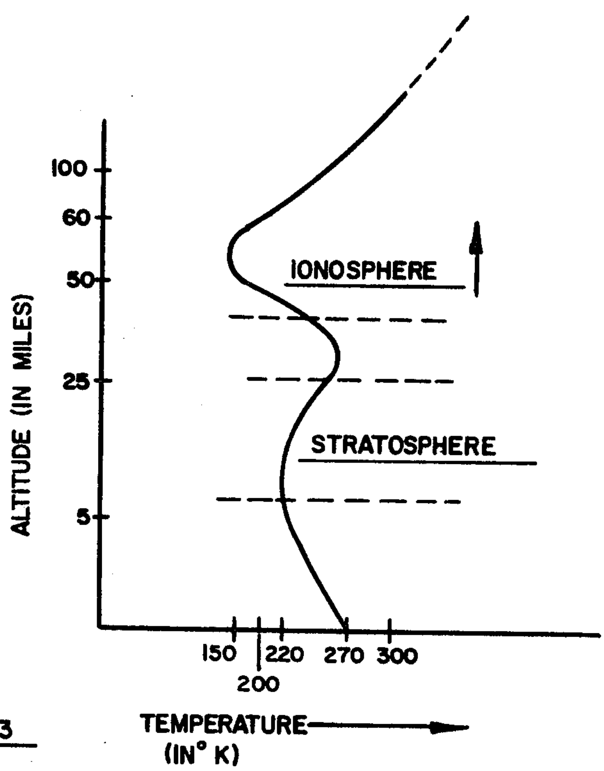

FIG. 3

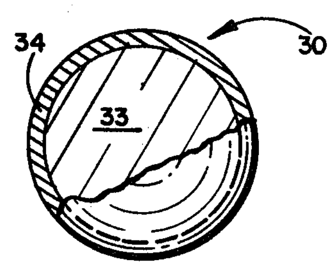

FIG. 2

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ARTIFICIAL ION CLOUD

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U.S. Cl. 343—18 10 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus and method for producing in the ozone layer an artificial ion cloud having sufficient electron density to reflect electromagnetic waves. Ablative coated microspheres of lithium hydride, sodium hydride, butyl lithium, or ethyl cesium are released through a nozzle in a vehicle passing through the stratosphere. The coatings ablate and the exposed compounds photoionize at the ozone layer ambient temperature to produce an ion cloud. As charge is neutralized, reionization occurs by light absorption producing a long lifetime cloud. Typically, a cloud of 2.1×10^{10} cubic feet of ionized gas having a charge density of 10^8 electrons/cm.^{3} may be produced with 0.8 pound of lithium hydride.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to an apparatus and process for producing artificial ion cloud. More particularly, the invention relates to production of an ion cloud by release in the stratosphere of ablative coated microspheres of a compound which is photoionizable at ozone layer ambient temperatures.

Background of the invention

Various applications exist for artificial ion clouds capable of refracting or reflecting electromagnetic radiation. For example, such clouds may be used to reflect radio signals between two points on the earth.

It is well known that meteor trails formed by ionization of ambient air at altitudes of about 56 to 68 miles exhibit radar cross-sections of 10^3 to 10^4 meter^2 for frequencies between 30 mHz. and 100 mHz. As described by J. S. Greenhow et al. (in the book entitled "Physics of the Upper Atmosphere," J. A. Ratcliffe editor, Academic Press, New York, 1960, beginning at p. 544) meteor trail ionization is short-lived, the constituent electrons being lost by diffusion, radiative recombination and attachments to atoms or molecules. It is these diffusion, recombination and attachment mechanisms which in the past have severely limited the lifetime of an artificial ion cloud.

Prior art artificial ion clouds primarily have been of the explosive or thermal reaction type. Typically, a high altitude bursting rocket was used to fire potassium nitrate and aluminum into the ionosphere. An aluminothermic reaction occurred, typically of an altitude of about 62 miles, yielding elemental potassium, nitrogen gas and aluminum dust. The potassium vapor, with an ionization potential of 4.32 ev., is ionized in the high temperature reaction producing sufficient free electrons so as to reflect electromagnetic radiation. In daylight at this 62 mile altitude the neutral potassium is photoionized, extending the lifetime of the cloud.

An alternative approach of the prior art was to use an explosive charge of RDX with cesium nitrate and aluminum. The elemental cesium produced by the reaction has an ionization potential of 3.86 ev., hence is photoionizable in the ionosphere.

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While these techniques were useful to produce an artificial ion cloud in the ionosphere, then exhibited disadvantages typical of explosive or thermal type reactions. For example, the percentage conversion of material into ions by explosive reaction is low, with much of the actual mass being converted into inert non-ionic products not useful for reflection of electromagnetic radiation. Since this net mass-to-change conversion is low, it is uneconomical to use these prior art techniques to produce artificial ion clouds. Moreover such prior art artificial ion clouds had to be produced at altitudes well above the stratosphere.

The present invention sets forth a technique and apparatus for producing an artificial ion cloud in the ozone layer, which cloud has a sufficient ion density to exhibit high reflectivity of electromagnetic waves. The technique has a high mass-to-change conversion factor and produces a cloud having a relatively long lifetime.

SUMMARY OF THE PRESENT INVENTION

In accordance with the present invention, there is set forth an apparatus and process for producing an artificial ion cloud in the ozone layer (stratosphere), which cloud is capable of reflecting electromagnetic waves. The technique utilizes photoionization of lithium hydride, sodium hydride, butyl lithium, or ethyl cesium packaged as ablative coated microspheres.

The ablative coated microspheres are metered out of nozzles in a vehicle passing through the stratosphere. When released, the coating ablates permitting the reactant to photoionize at the ambient temperature of the ozone layer. For example, lithium hydride photoionizes to produce ionized elemental lithium and free electrons. As charge neutralizes in the artificial cloud thus produced, reionization occurs by light absorption, greatly increasing the lifetime of the cloud. Since the reaction follows homogeneous kinetics, essentially 100% conversion may be achieved.

Thus it is an object of the present invention to provide an artificial ion cloud.

Another object of the present invention is to provide a technique for producing in the stratosphere an artifical ion cloud capable of refracting or reflecting electromagnetic radiation, and having relatively long lifetime.

Yet another object of the present invention is to provide an ion cloud in the ozone layer by continuous photoionization of lithium hydride, sodium hydride, butyl lithium, or ethyl cesium.

Another object of the present invention is to provide a technique for producing an artificial ion cloud by releasing into the upper atmosphere ablative coated microspheres of a compound which photoionizes at upper atmosphere ambient temperatures.

These and other objects and features of the present invention will become clear in conjunction with the following illustrative drawings and description of the preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified perspective view, in partial section, of a vehicle equipped to produce an artificial ion cloud in accordance with the present invention. The vehicle is illustrated as passing through the stratosphere and behind it an ion cloud capable of reflecting electromagnetic radiation.

FIG. 2 is a greatly enlarged perspective view, in partial section, of a typical ablative covered microsphere containing a photoionizable compound useful for producing an artificial ion cloud in accordance with the present invention.

FIG. 3 is a graph of temperature as a function of altitude for various atmospheric regions.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates production of an artificial ion cloud **20** in accordance with the present invention. As shown in FIG. 1, vehicle **10** comprises a ballistic rocket, a satellite re-entry vehicle, or the like. Mounted within vehicle **10** is supply reservoir **12** which reservoir is adapted to store an appropriate quantity of free-flowing ablative coated microspheres **30**. As described hereinbelow in conjunction with FIG. 2, microspheres **30** each contain a compound which photoionizes at the ambient temperature of the atmospheric level at which artificial ion cloud **20** is to be produced. Preferably, cloud **20** is produced in the ozone layer of the stratosphere, from about 10 miles to about 38 miles above sea level.

Vehicle **10** (see FIG. 1) is equipped with appropriate pump **14** or equivalent device for withdrawing microspheres **30** from reservoir **12** and for supplying them at a controlled rate to nozzle **16**. Preferably microspheres **30** are emitted from nozzle **16** at a relatively uniform rate as vehicle **10** passes through the atmospheric layer in which cloud **20** is to be produced.

As illustrated in FIG. 1, microspheres **30** emitted from nozzle **16** form cloud **20** in the wake of vehicle **10**. As microspheres **30** are shot from nozzle **16** they encounter sufficient resistive force due to collisions with ozone and other atoms or molecules present in the stratosphere to cause ablation of the microsphere coating. This releases the photoionizable compound from microsphere **30**, which compound photoionizes in the presence of sunlight **22** to produce free electrons. Artificial ion cloud **20** thus produced is of sufficient electron density as to be capable of reflecting electromagnetic radiation.

The manner in which artificial ion cloud **20** is produced may be understood more fully in conjunction with FIG. 2, which shows a greatly enlarged view of typical microsphere **30**. The actual size of microsphere **30** is not critical, and typically is of millimeter range. Each microsphere **30** comprises a core **33** of a compound which is photoionizable at the ambient temperatures of the atmospheric region in which cloud **20** is to be produced. Core **33** is surrounded by ablative coating **34** which typically comprises a low melting microcrystalline wax. Of course, other ablative materials well known to those skilled in the art also may be used for coating **34**. Although coating **34** is illustrated as being of uniform thickness, this is not a requisite of the invention.

Microspheres **30** may be produced by micro-encapsulation techniques well known to those skilled in the art, and typified by that described in the U.S. Patent to Brynko et al. Pat. No. 3,190,837. Such micro-encapsulation provides microspheres **30** which collectively have a free-flowing consistency not unlike granulated sugar. Individual microspheres **30** have coatings **34** of somewhat random thickness, resulting in correspondingly random ablation times when released from vehicle **10** in the stratosphere. This random ablation time aids in dispersion fo microspheres **30** to produce cloud **20** of maximal size.

Materials which have been found optimum for use as core **33** of microsphere **30** include lithium hydride (LiH), sodium hydride (NaH), butyl lithium (C_4H_9Li), or ethyl cesium (C_2H_5Cs). These are all extremely energetic compounds which photoionize by the following reactions:

$$LiH+h\nu\rightarrow Li^{+}+e^{-}+H \quad (1)$$
$$NaH+h\nu\rightarrow Na^{+}+e^{-}+H \quad (2)$$
$$C_4H_9Li+h\nu\rightarrow Li^{+}+e^{-}+C_4H_9 \quad (3)$$
$$C_2H_5Cs+h\nu\rightarrow Cs^{+}+e^{-}+C_2H_5 \quad (4)$$

As indicated in the graph of FIG. 3, ambient temperature in the stratosphere range from about 220° K. to about 270° K. All of the compounds (LiH, NaH, C_4H_9Li and C_2H_5Cs) suggested hereinabove for use as microsphere core **33** will photoionize in this temperature range.

If microspheres **30** are appropriately metered out by nozzle **16** (see FIG. 1), a cloud **20** of about 2.1×10^{10} cubic feet, having an average charge density of 10^8 electrons/cm.³, may be produced with the following amounts of photoionizable core 33 compound.

Compound	Amount (in pounds)
LiH	0.8
NaH	2.4
C_4H_9Li	6.4
C_2H_5Cs	16.2

Typically, 0.8 pound of lithium hydride will provide 0.7 pound of ionized elemental lithium and yield about 5×10^{22} free electrons. By distributing this into a cloud of 2.1×10^{10} cubic feet, a charge density of 10^8 electrons/cm.³ may be obtained.

The ability of artificial ion cloud **20** to reflect electromagnetic radiation may be expressed in terms of its radar cross section. As discussed at p. 626 of the text "Introduction of Radar Systems" by Merrill I. Skolnick, McGraw-Hill, New York, 1962, the radar cross section of an electron is defined as the power scattered into a unit solid angle per unit incident power density. For backscatter radar, $\sigma_e=8\times10^{-30}$ meters². The cross section σ_v per unit volume of a cloud of electrons having a density of N electrons per cubic meter, all of which electrons scatter incoherently, is given by

$$\sigma_v=N\sigma_e \quad (5)$$

Substituting a value of $N=10^8/\text{cm.}^3=10^{14}/\text{m.}^3$ into Equation 5 indicates that for a cloud of charge density 10^8 electrons/cm.³ the theoretical radar cross section will be $\sigma_v=8\times10^{16}/\text{m.}^2$, a very considerable value.

The frequency f of a signal which would be totally reflected from an ion cloud having a charge density of 10^8 electrons/cm.³ may be found from the equation:

$$f^2=81\ N \quad (6)$$

where N is the number of electrons per cubic meter. Equation 6 is set forth in Skolnick, op. cit., at p. 624. Substituting $N=10^8/\text{cm.}^3=10^{14}/\text{m.}^3$ into Equation 6, it may be seen that $f=90$ mHz. Of course, signals at frequencies lower than this also will be reflected from cloud **20**.

As noted hereinabove, a number of mechanisms at work in the upper atmosphere tend to reduce the actual number of free electrons available in cloud **20**. At higher altitudes, attachment and radiation recombination are the predominating mechanisms. For example, at an altitude of 81 miles reduction in charge density from 10^{10} electrons/cm.³ to 10^8 electrons/cm.³ will occur in about 10 seconds.

At lower altitudes diffusion is the predominating decay process, and is altitude dependent. For example, at an altitude of 56 miles, the time required for an ion cloud to decay from 10^8 electrons/cm.³ to 10^6 electrons/cm.³ is about 250 seconds, while at an altitude of 50 miles the time required for equivalent reduction in charge concentration is only 6 seconds. Note that these attachment, radiation recombination, and diffusion charge reduction mechanisms were the primary factors limiting the lifetime of prior art artificial ion clouds produced in the ionosphere by explosive or thermal type reactions.

When artificial ion cloud **20** (see FIG. 1) is produced in the stratosphere, the same charge decay mechanisms are present. However, the attachment and radiation recombination mechanisms merely serve to regenerate the original photoionizable compound. For example, the Li^+ and H produced by reaction (1) typically recombine to form LiH, which itself is photoionizable. Thus, in the presence of sunlight the inventive artificial ion cloud **20** tends to regenerate itself, greatly prolonging the lifetime of the cloud. Of course, the cloud still tends to diffuse, so that, even in sunlight, the charge density gradually will diminish. (Note in this regard that the typical density value of 10^8 electrons/cm.^{3} used in the description above generally is applicable to the cloud as formed, and will diminish with time.)

A typical application of an artificial ion cloud produced in accordance with the present invention is to provide a short term VHF transmission path. For example, such a reflective cloud could facilitate television transmission from a portable transmitter to a remote receiving station and would be useful to provide a line TV coverage of a news event from a remote location using a relatively low power portable transmitter. A small rocket, equipped with appropriate microsphere dispensing equipment such as that illustrated in FIG. 1, may be lobed into the stratosphere at an appropriate location between the remote transmitting site and the receiving station. When released, the microspheres would produce an ion cloud of sufficiently high reflectivity to permit good TV reception at the receiving station, despite the use of a very low power transmitter.

Although the invention has been described in detail, it is to be understood that the same is by way of illustration and example only, and is not to be taken by way of limitation, the spirit and scope of this invention being limited only by the terms of the appended claims.

I claim:

1. A process for producing an artificial ion cloud, said process comprising the steps of:
   releasing in the upper atmosphere a compound selected from the class consisting of lithium hydride, sodium hydride, butyl lithium and ethyl cesium.

2. The process defined in claim 1 wherein said compound forms the core of ablative coated microspheres.

3. A process for producing an atificial ion cloud, said process comprising the steps of:
   passing a vehicle through the stratosphere, and releasing from said vehicle ablative coated microspheres of a compound selected from the class consisting of lithium hydride, sodium hydride, butyl lithium and ethyl cesium.

4. The process defined in claim 3 wherein said microspheres are released as said vehicle passes through the ozone layer.

5. The process defined in claim 3 wherein said microsphres are coated with low melting microcryystalline wax.

6. The process defined in claim 3 wherein said cloud is produced in sunlight.

7. An apparatus for producing an artificial ion cloud comprising:
   a vehicle adapted for passage through the stratosphere,
   means, situated on said vehicle, for releasing ablative coated microspheres from said vehicle during passage through the stratosphere, said microspheres comprising a compound selected from the class consisting of lithium hydride, sodium hydride, butyl lithium, and ethyl cesium.

8. An apparatus as defined in claim 7 wherein said microspheres each are coated with an ablative microcrystalline wax.

9. An apparatus as defined in claim 7 wherein said means comprises:
   a reservoir for storing said microspheres,
   nozzle means for emitting said microspheres from said vehicle, and
   means for withdrawing said microspheres from said reservoir and for providing said microspheres to said nozzle means at a controlled rate.

10. As a material for producing an artificial ion cloud in the stratosphere, ablative coated microspheres of a compound selected from the class consisting of lithium hydride, sodium hydride, butyl lithium or ethyl cesium.

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U.S. Cl. X.R.

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