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An Electromagnetically Levitated Two-Axis Gimbaless Pointing Mechanism

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Introduction

This is a brief description for a proposed new pointing mechanism which requires no mechanical gimbals, is virtually friction free, and is vibration isolated from a ground support system or vehicle. The device uses electromagnetic forces for support levitation and pointing, both being accomplished from a ground reference thereby leaving the payload virtually free from a remotely located command center. Solid pointing angles of almost 2π steradians are achievable, limited only by structural interference. A third degree-of-freedom tilt axis can be added at will, but will not be elaborated here. Although the system is primarily intended for space vehicles in a micro-gravity environment, earth-ground support is possible with superconducting electromagnets.

Description

Figure 1 shows the basic mechanism. The large ball or hollow sphere connected to ground contains 29 electromagnets for support (15 in each of two orthogonal planes with one being shared), and three mutually orthogonal winding loops (A, B, and C) which control pointing. Shown in the figure are 15 stator electromagnets, nine of which combine with the rotor's electromagnets to support the payload for rotation angle θ about the z axis (see key). Not shown are 14 additional stator electromagnets which circumvent the sphere in the x-z plane for rotation angle ϕ about the Y axis, and 8 rotor electromagnets in the same plane.

With winding loops A,B,C de-energized, consider the payload in the reference vertical position. Dc current sources drive all 29 stator electromagnets and 17 rotor electromagnets forming 17 north-north pole pairs. Repulsive levitation is generated by 16 electromagnets with the exception being magnet 5. The stator current in magnet 5 is driven with an opposite polarity current to provide a necessary attractive vertical component balancing force. The gravity vector shown also acts vertically downward. A sketch showing the flux line pattern for the levitating magnets in the aligned state is shown in figure 2. The north poles' flux lines return via a south pole sandwich. Each south pole is designed to be narrower than the main north pole to reduce the north-south attractive forces. The south pole material therefore must be specially selected to withstand the higher flux densities as illustrated in figure 2.

As the rotor turns, the aligned state is altered so that its north poles become temporarily positioned above stator's south poles and vice-versa so that undesirable attractive forces can be developed. To

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reduce this effect, the south pole magnets may be scalloped, that is, material is removed from them, as shown in figure 3. This increases the air gap reluctance path between a north-south pole pair resulting in the flux line pattern shown in figure 3a.

Pointing Control

To establish the vertical reference position, winding loop A is energized with an ac voltage source. By transformer action this causes a voltage to be induced in magnet P located colinear with the north pole levitating magnet 5 on the rotor. With the winding of magnet P terminated in a resistor, an ac current flows which produces a self-aligning dc torque in the y direction. Demagnetization of the levitating magnets will not occur because they offer a very high impedance to ac current due to the steady dc current from the current source drive which maintains proper levitation independent of the ac pointing field. The ac pointing field frequency is to be selected so as to minimize core and eddy current losses. The heating losses due to the resistive termination of magnet P are used to control damping.

When loop B is energized in addition to loop A, the resultant pointing field will point in, say, the direction y' (loop C is still de-energized). Again by induction in magnet P only, the dc restoring torque causes the payload to rotate through an angle θ to align magnet P with the y' direction. As the rotor turns, the force balance remains intact except for a small unevenness due to north-south pole attraction as previously discussed. Any force unbalance caused by this unevenness is detected by the Hall effect sensors and is compensated for. It is worth noting that although such unbalances do produce velocity variations, pointing accuracy is not affected in an equilibrium position.

When loop C is energized a flux density component out-of-the-page gives a resultant B vector a ϕ pointing angle component to which the payload magnet P, and hence the payload, must align.

A crucial problem which is anticipated is the extent to which the resultant pointing flux field is localized. If it is perfectly localized along a straight line then it cannot couple into the aligning magnet P. As the field spreads or mushrooms then coupling becomes a reality. But if the mushrooming is too large, then pointing direction becomes ambiguous. For this reason, a detailed investigation is required for the optimum design of the pointing magnetic circuit design.

SUMMARY

To summarize, a mechanism has been described to support and point an instrument in a low gravity environment. Dc electromagnets provide a stiff electromagnetic levitating force field, whereas a moderately stiff ac pointing control system creates a rolling action of the moving member upon the dc electromagnetic field. Further, the possibility of using superconducting magnets allows for the possibility of non-contact ground support and control.

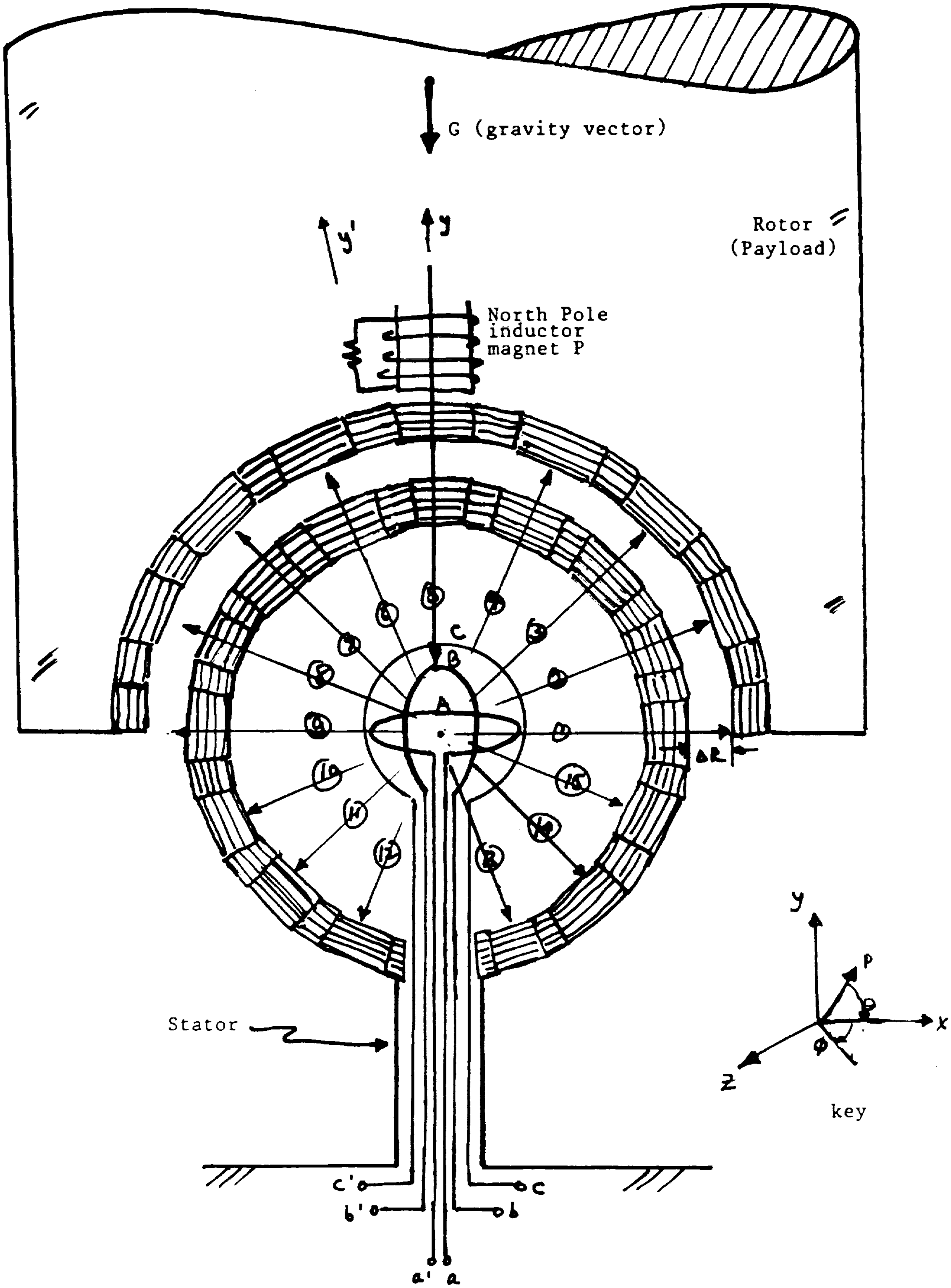

Fig 1 Electromagnetic Levitation Pointing Mechanism

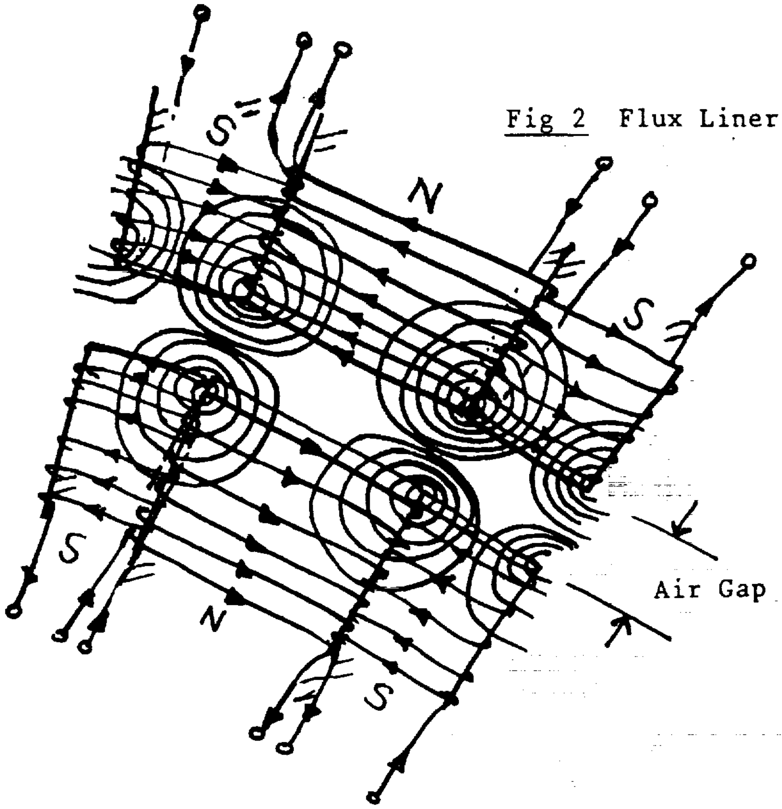

Fig 2 Flux Liner in Aligned State

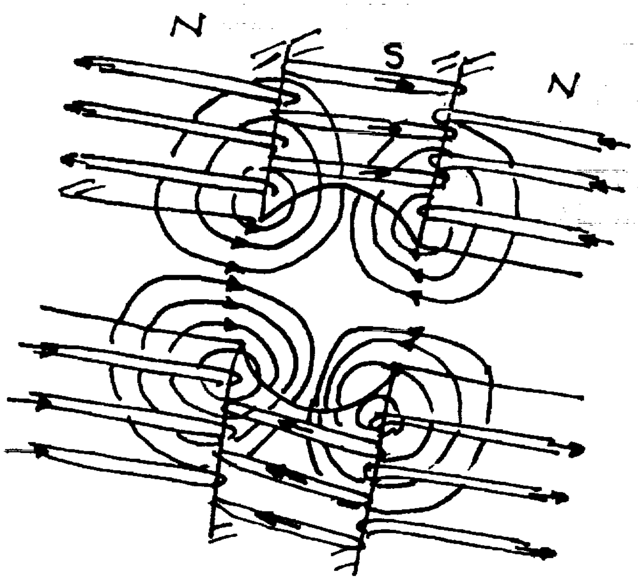

Fig 3 Scalloped South Poles in Aligned State

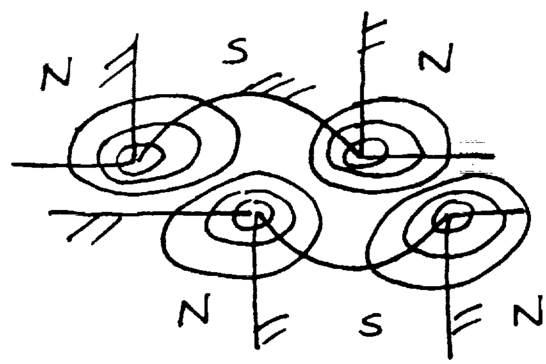

Fig 3a Increased Reluctance at South Poles reduces Attractive Forces in Quadrative State