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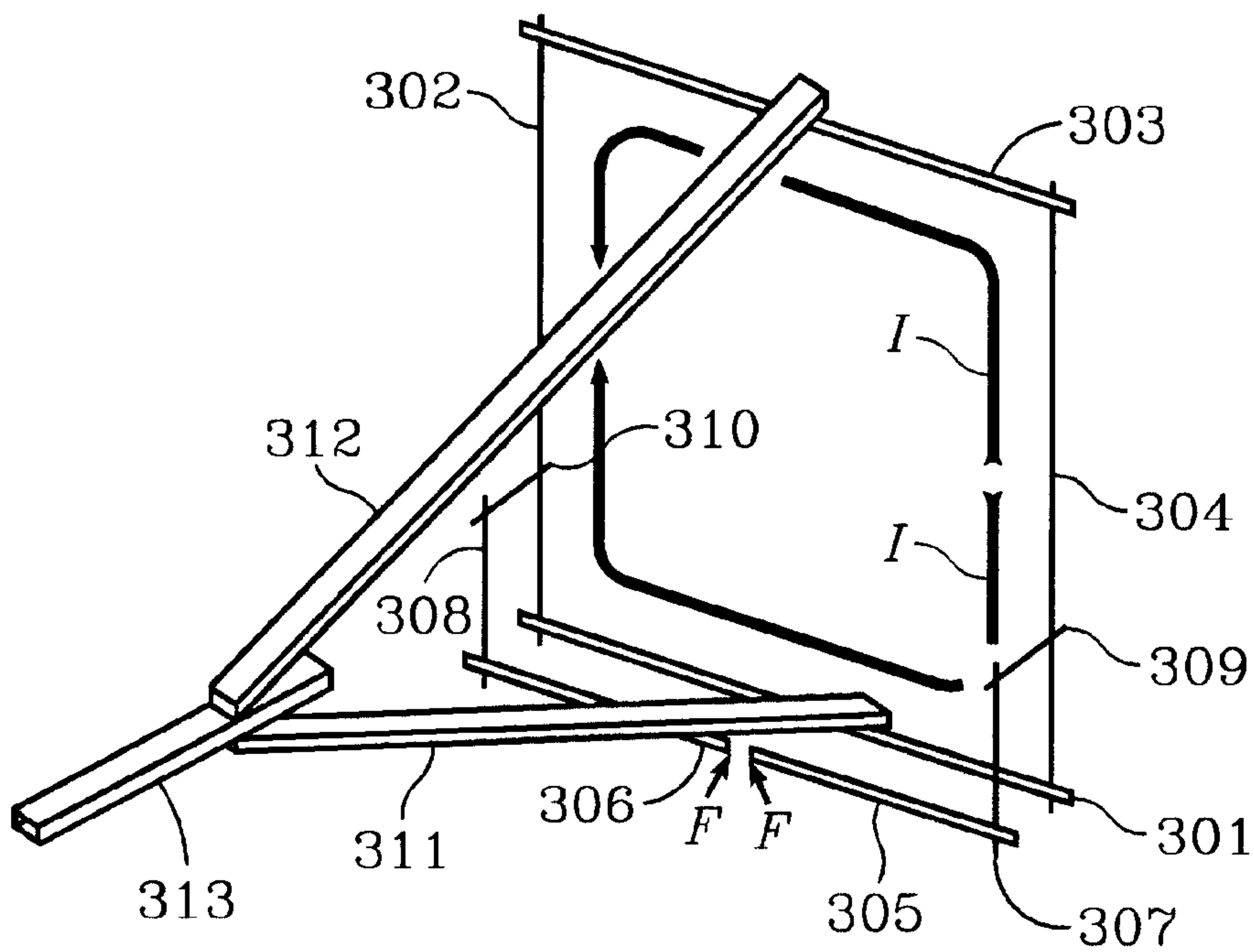
(54) Title: DIAGONAL SUPPORTING CONDUCTORS FOR LOOP ANTENNAS



(57) Abrégé/Abstract:
Supporting conductors for loop antennas that are positioned within the principal H plane of the loop antennas and positioned diagonally with respect to the plane of the loops. Such diagonal supporting conductors do not interfere with the electrical operation of the loop antennas, and they can be stronger than the traditional long supporting insulators that are often broken by bad weather. These conductors may also reduce the movement of the loop antennas in the wind and may have less weight and cost than the combination of a supporting conductor placed directly across the loop plus a supporting boom.

Abstract of The Disclosure

Supporting conductors for loop antennas that are positioned within the principal ***H*** plane of the loop antennas and positioned diagonally with respect to the plane of the loops. Such diagonal supporting conductors do not interfere with the electrical operation of the loop antennas, and they can be stronger than the traditional long supporting insulators that are often broken by bad weather. These conductors may also reduce the movement of the loop antennas in the wind and may have less weight and cost than the combination of a supporting conductor placed directly across the loop plus a supporting boom.

Diagonal Supporting Conductors for Loop Antennas

Previous disclosures have shown that it is practicable and desirable to support loop antennas with conductors connected directly across the loops from a balanced feed point to the opposite side of the loops. This is more desirable than supporting such loops with long insulators that can be broken more easily by bad weather. This system of supports also allows the whole antenna to be grounded for direct currents for some measure of lightning protection. The present disclosure shows that it also is possible to support such loops with conductors that are placed in the plane that is perpendicular to the plane of the loops. Particularly, it is convenient to have such supporting conductors mounted diagonally with respect to the plane of the loops. Hereinafter in this description and the attached claims, such conductors will be called diagonal supporting conductors. In some cases, such supports may be less heavy and less expensive than the combination of the supports directly across the loops plus the usual supporting boom. In other cases, it is a considerable advantage that such diagonal supporting conductors can reduce the motion of the loops in the wind and, thereby, preserve the proper electrical operation of the antenna in the wind.

The background of this invention as well as the objects and advantages of the invention will be apparent from the following description and appended drawings, wherein:

Fig. 1 illustrates a perspective view of a loop antenna element with a supporting conductor connected directly across the loop;

Fig. 2 illustrates the conventional principal planes passing through a rectangular loop antenna element;

Fig. 3 illustrates a perspective view of a loop antenna element supported by diagonal supporting conductors, and best illustrates the essence of the invention;

Fig. 4 illustrates a perspective view of a multiloop antenna element that has both supporting conductors placed directly across the loops and supporting conductors placed diagonally with respect to the loops;

Fig. 5 illustrates a perspective view of a loop antenna element supported by several diagonal supporting conductors; and

Fig. 6 illustrates a perspective view of an array of loops antenna elements supported by diagonal supporting conductors.

Canadian patent 2,223,668[1] on *The Strengthened Quad Antenna Structure* disclosed that it was possible and desirable to support one-wavelength loop antenna elements with conductors connected directly across the loop from the balanced feed point to the opposite point of the loop. This is illustrated by Fig. 1, with parts **101A**, **101B**, and **102** to **107**. The justification for this action, as was explained in that patent, will follow but, first, the diagrams require some explanation.

In these diagrams, the parts are generally numbered according to their function. That is, although the loop in Fig. 1 could be made from one bent conductor, it is convenient to assign a number to each of the four sides of the loop. Therefore, the whole of the bottom side of the loop is assigned one number, **102**, even though it is broken by the generator symbols.

In addition to the lines representing the conductors, there are wide arrows in Figs. 1, 2 and 3 to indicate some aspects of the currents. That is, these arrows indicate that current maxima are at the centres of the arrows, current minima are where the arrowheads and arrow tails face each other, and the current maxima are very approximately out of phase with each other at adjacent arrows of particular current paths. However, not much else should be assumed about these currents. Particularly, it should not be assumed that different currents necessarily have the same magnitudes and phases just because they are all called *I* or that there are sudden changes in phase where the arrowheads and arrow tails face each other.

In order to understand the following explanation, it also is necessary to introduce some terms. In Fig. 2, with parts **201** to **205**, part **202** illustrates the plane of the loop, **201**. Because the magnetic field is perpendicular to the main current paths at the top and bottom of the loop, plane **203** illustrates the plane of the magnetic field. Because this plane passes through the centre of the loop, hereinafter in this discussion and attached claims, it will be called the principal ***H*** (magnetic field) plane, as is conventional practice. Likewise, the plane that passes through the centre of the loop and that is perpendicular to both the plane of the loop and the principal ***H*** plane, **204**, will hereinafter be called the principal ***E*** (electric field) plane, as is also conventional practice.

If the loop were symmetrical with respect to the ground, and the loop were fed in a balanced manner, the feed point would be at ground potential for radio frequencies. In Fig. 1, the two generator symbols, **101A** and **101B**, are there to indicate that the loop is fed in a balanced manner with respect to ground. Because of the symmetry, away from that feed point there would be instantaneous voltages of equal magnitude but of opposite polarities at places that are equidistant from the feed point. The voltages would be of opposite polarities because no net current would flow between these points if they had voltages of the same polarity. At the point of the loop opposite from the feed point, in the centre of part **104** in Fig. 1, these voltages of equal magnitude and opposite polarity would be the same voltage. The only voltage that satisfies those criteria is zero volts. That is, whatever the voltages would be at other places on the loop, they would reach zero at the place opposite the feed point. That is, that point would be at ground potential for radio frequencies.

Therefore, a conductor, part **106**, could be connected between those two grounded points and no current would flow in it because of that connection. Also, since the currents in corresponding parts of the two sides of the structure are equal in magnitude and opposite in phase, they will not induce any net voltage in the added central conductor. The top and bottom sides, **102** and **104**, would not induce any significant voltage in part **106** because they are perpendicular to part **106**. That is, if the loop were fed in a perfectly balanced manner, this additional conductor would have no electrical effect on the operation of the structure.

Of course, a perfect balance is not possible, but a reasonably balanced loop would produce an insignificant amount of current in the central conductor. Indeed, it is amazing how little current flows in this central conductor even when the structure is fed in an unbalanced manner. However, a balanced feeding system is preferred.

Note that the above explanation is not dependent on particular loop sizes. That is, although such loops usually have perimeters of one wavelength, loops of other sizes also could be supported in the same manner. Another way to view the point is to note that a loop would not be upset by such supports if it were used at frequencies other than at its resonant frequency. Also note that the shape of the loop is not significant to the above discussion. If the loop were symmetrical about the principal ***H*** plane, it could be circular or triangular, for example.

The idea of supporting loop antenna elements by conductors connected to the places that are at ground potential is not new. *The Antenna Experimenter's Guide* by Peter Dodd[2] shows such a supporting system with the supporting conductors positioned perpendicular to the plane of the loop. The difficulty with this system is that if the antenna were rotated around a tower, the antenna should be positioned entirely above the tower so that the bottom support would not interfere with the tower. This system also requires that the mast extend up to the top supporting conductor, which would increase the weight and cost. Particularly if the antenna were large, it would be better to have the antenna attached to the mast at the centre of the loops to minimize the stress on the mast. The system of the strengthened quad accomplishes that goal.

In Fig. 3, with parts **301** to **313**, instead of having a conductor, **106**, connected right across the loop to a boom, **107**, there are two conductors, **311** and **312**, mounted in the principal ***H*** plane and mounted diagonally with respect to the plane of the loop. They might connect to a boom, **313**, or to a mast. These two conductors, **311** and **312**, are the diagonal supporting conductors.

Also different from Fig. 1, instead of two generator symbols indicating a balanced feeding system, Fig. 3 has a T matching system. Except for the extensions, **307** and **308**, to the conventional T parts, **305** and **306**, it is a conventional T matching system. Usually the sides of a one-wavelength square loop are short enough that a convenient match cannot be obtained without such extensions. The usual tuning capacitors and balanced-to-unbalanced transformer attached to the feed points (*F*) were not shown because they are conventional and would unnecessarily complicate the diagram.

If the loop were balanced, because of the balanced T match, the centres of both the top and bottom of loop, **301** and **303**, should be at ground potential for radio frequencies. Therefore, no currents should flow in the diagonal supporting conductors and the boom, **311**, **312** and **313**, from that connection because they are connected to the grounded points. Also, because the diagonal supporting conductors are in the principal ***H*** plane, which is perpendicular to the plane of the loop and perpendicular to parts **301** and **303**, these parts of the loop would not induce voltages into the diagonal supporting conductors. The sides of the loops, **302** and **304**, would induce voltages into the diagonal supporting conductors, **311** and **312**, because these conductors are partially parallel to these two sides of the loop. However, because the currents in the corresponding parts of the sides of the loops are flowing in opposite directions, no net voltages would be induced in the diagonal supporting conductors. Similar arguments could be made for the radiation from the parts of the T matching system. Therefore, these diagonal supporting conductors would have no electrical effect on the operation of the loop as long as they were entirely in the principal ***H*** plane.

Whether the pair of diagonal supporting conductors of Fig. 3 would be lighter and less expensive than the boom and single supporting conductor of Fig. 1 depends on the dimensions. It is perhaps obvious that if conductors **311** or **312** were approximately as long as either conductors **106** or **107**, there would be no advantage in weight or cost. Between these extremes, there could be such an advantage. However, there is another advantage. In windy conditions, the arrangement of Fig. 1 would allow conductors **102** and **104** to move back and forth rather easily. That is, more strength would be required to reduce the movement in windy conditions than the strength required just to avoid a mechanical failure. Since conductors **102** and **104** carry the maximum current and are, therefore, the most important parts of the loop, when they change their positions relative to the other loops in the antenna, they change the performance of the antenna. Because there are two diagonal supporting conductors in Fig. 3 attached to the centres of the high-current parts of the loop, those parts of the loop would move less in the wind.

For a set of loops, such as the centre-fed *Quadruple-Delta Antenna Structure* of Fig. 4 and Canadian Patent 2,175,095[3], the same kind of diagonal supporting conductors can be used. The feeding system was not shown because it would be conventional and it would unnecessarily complicate the diagram. If the set of loops were symmetrical with respect to the principal ***H*** plane, the voltages in the conductors on one side of the antenna would be equal in magnitude and opposite in phase from the voltages on the opposite side. Therefore, the voltages at the outer points must be zero volts. Likewise, the radiation from one side of the antenna to any supporting conductors in the principal ***H*** plane would be cancelled by the radiation from the other side. Therefore, the diagonal supporting conductors would have no currents in them no matter how many loops were in such a set of loops.

This problem of the antenna moving in the wind is likely to be more severe with large multiloop antenna elements like the quadruple delta. Because of its size, it probably would move more than a smaller antenna. In addition, an antenna using such elements probably would have a higher gain and, therefore, the distances between the elements probably would be more critical. For that reason, it could be worthwhile to support the quadruple delta antenna, with parts **401** to **411**, with both a boom, **413**, and a conductor directly across the element, **412**, plus diagonal supporting conductors **414** and **415**. If such a large antenna element were supported only at the top and bottom, it may be that the centre would move too much in the wind.

One may get the impression that this multitude of supports would produce a rather heavy and expensive system, but that may not be the case. These additional supporting conductors might not simply add weight and cost, because they would support the antenna elements as well as provide a means of reducing the movement in the wind. That is, the additional diagonal supporting conductors may allow a reduction in the weight and cost of the boom, and the conductor positioned directly across the element may not be needed at all.

The idea of the diagonal supporting conductors meeting each other at a central point, as in Figs. 3 and 4, has the same advantage as has the strengthened quad when the antenna is rotated. That is, there are no parts below the centre of the loops that would interfere with the tower when the antenna is rotated around the tower. However, not all antennas are rotated and sometimes towers are rotated. If the loop were large, it might be necessary to support the loop with several diagonal supporting conductors, as in Fig. 5. In this diagram, the loop with parts **501** to **504** has four diagonal supporting conductors, **505** to **508**, to connect it to a mast, **509**. The mast, of course, could be a tower. Since all of the diagonal supporting conductors are in the principal ***H*** plane, they should have no significant effect on the electrical performance of the loop. Whether the diagonal supporting conductors are positioned diagonally toward the centre of the structure or diagonally away from centre would make no significant difference to the electrical performance of the loop.

A more common situation is illustrated by Fig. 6, with parts **601** to **628**. It is common practice in amateur radio to have an antenna that covers the three bands at 14, 21 and 28 megahertz. A common example is the boomless quad, which resembles Fig. 6. In this diagram, parts **601** to **608** would be a two-element Yagi-Uda array for the lowest frequency band, and parts **609** to **616** plus parts **617** to **624** would likewise serve the higher frequency bands. In the traditional antenna, there would be eight long insulators extending from the central point to the eight trios of corners of the square loops. Because there are three sets of loops carried by the long insulators, the stress on the insulators would be severe in an ice storm. In Fig. 6, only four diagonal supporting conductors, **625** to **628**, are needed to do the same job. Because the diagonal supporting conductors are metal, they can made as strong as is necessary. In addition, because of the stress on the long insulators, the loops are traditionally made with small diameter wires to reduce the weight, but this reduces the bandwidth of the antenna. With the diagonal supporting conductors, the loops can be made of large tubing to increase the bandwidth.

Although it is usual practice to use conductors of circular cross-section for antennas, there is no such need for the diagonal supporting conductors. Radio-frequency currents tend to flow in the outer parts of conductors, because of the skin effect, so the currents tend to flow in the corners of square conductors, for example. Therefore, it is better to use round conductors for antennas, because there is more metal in their outer parts since the entire surfaces are their outer parts. However, the diagonal supporting conductors should not have currents flowing in them, so there is no electrical reason for not using other shapes for supporting conductors, like parts **311** and **312** in Fig. 3. Likewise, there is no electrical reason to avoid a relatively poor conductor, like steel, instead of the usual antenna materials, aluminum and copper. It also is possible to use tubes or solid rods for diagonal supporting conductors. Tubes usually are less expensive in large sizes and rods are less expensive in small sizes.

While this invention has been described in detail, it is not restricted to the exact embodiments shown. These embodiments serve to illustrate some of the possible applications of the invention rather than to define the limitations of the invention.

References

1. Podger, J. Stanley, *The Strengthened Quad Antenna Structure*, Canadian Patent 2,223,668, Classes H01Q 1/36 and H01Q 21/00, 11 July 2000.

2. Dodd, Peter, "Design of An All-Metal Quad," *The Antenna Experimenter's Guide*, 2nd ed. (Potters Bar, Hertfordshire: Radio Society of Great Britain, 1996), pp. 98-99.

3. Podger, J. Stanley, *The Quadruple-Delta Antenna Structure*, Canadian Patent 2,175,095, Class H01Q 01/36, 09 February 1999.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A diagonal supporting conductor for an approximately coplanar loop antenna, such that:

said loop antenna is approximately symmetrical with respect to the principal ***H*** plane of said loop antenna;

said loop antenna is fed in an approximately balanced manner;

said loop antenna is fed at a point on said loop antenna that is approximately at said principal ***H*** plane;

said diagonal supporting conductor is electrically and mechanically connected from a supporting boom, mast or tower to a place on said loop antenna that is approximately at ground potential for the frequency of operation;

said diagonal supporting conductor is disposed diagonally with respect to the plane of said loop antenna; and

said diagonal supporting conductor is disposed so that said diagonal supporting conductor is substantially within said principal ***H*** plane of said loop antenna.

2. The diagonal supporting conductor of claim 1 wherein the cross-sectional area of said diagonal supporting conductor is tubular.

3. The diagonal supporting conductor of claim 1 wherein the cross-sectional area of said diagonal supporting conductor is solid.

4. The diagonal supporting conductor of claim 1 wherein the cross-sectional area of said diagonal supporting conductor is circular.

5. The diagonal supporting conductor of claim 1 wherein the cross-sectional area of said diagonal supporting conductor is rectangular.

6. The diagonal supporting conductor of claim 1 wherein the cross-sectional area of said diagonal supporting conductor is square.

7. The diagonal supporting conductor of claim 1 wherein said loop antenna has only one

loop with a perimeter of approximately one operating wavelength.

8. The diagonal supporting conductor of claim 1 wherein said loop antenna has more than one loop.

9. A plurality of diagonal supporting conductors for an approximately coplanar loop antenna, such that:

said loop antenna is approximately symmetrical with respect to the principal ***H*** plane of said loop antenna;

said loop antenna is fed in an approximately balanced manner;

said loop antenna is fed at a point on said loop antenna that is approximately at said principal ***H*** plane;

each of said diagonal supporting conductors is electrically and mechanically connected from a supporting boom, mast or tower to a place on said loop antenna that is approximately at ground potential for the frequency of operation;

each of said diagonal supporting conductors is disposed diagonally with respect to the plane of said loop antenna; and

each of said diagonal supporting conductors is disposed so that each of said diagonal supporting conductors is substantially within said principal ***H*** plane of said loop antenna.

Fig. 1
Prior Art

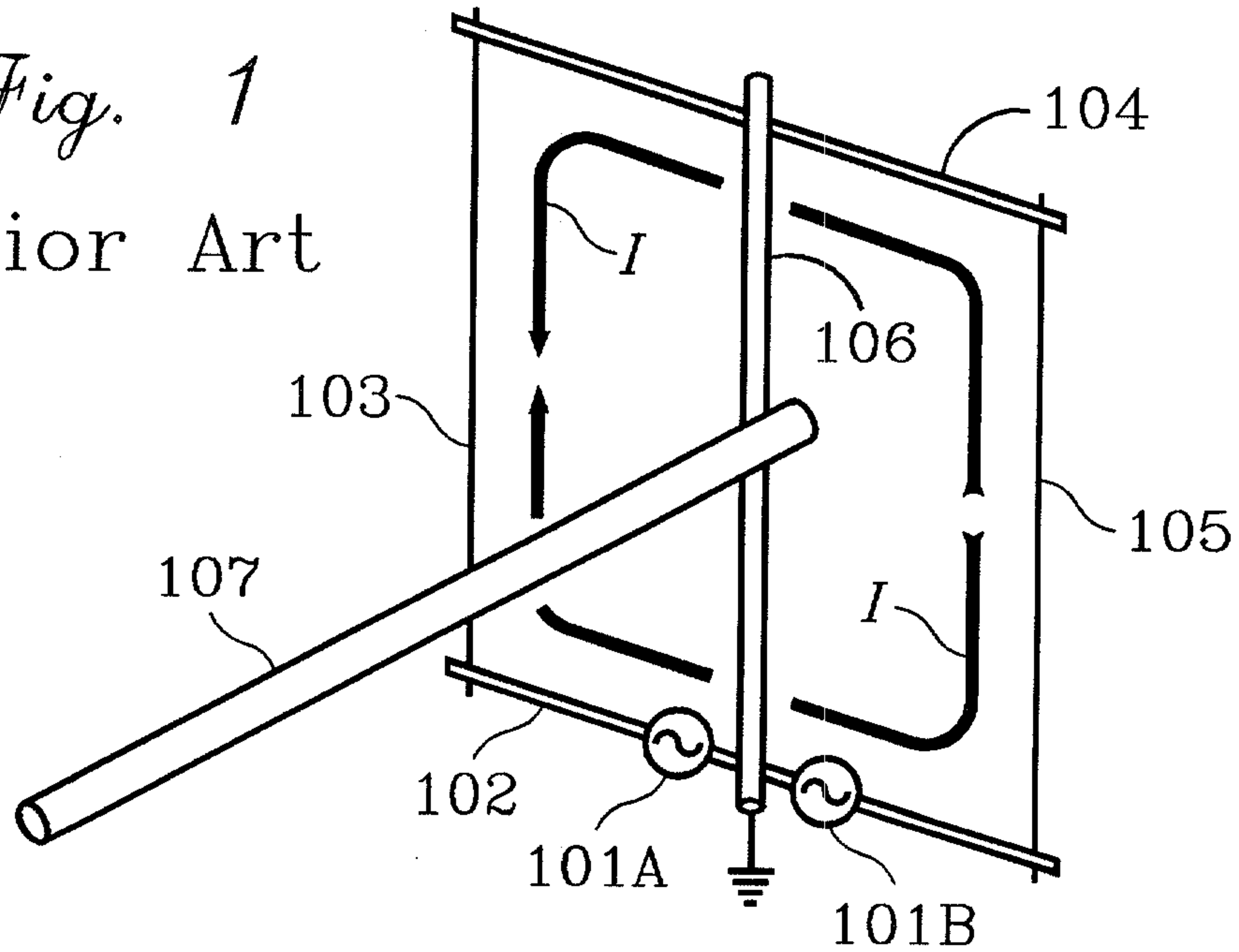


Fig. 2
Prior Art

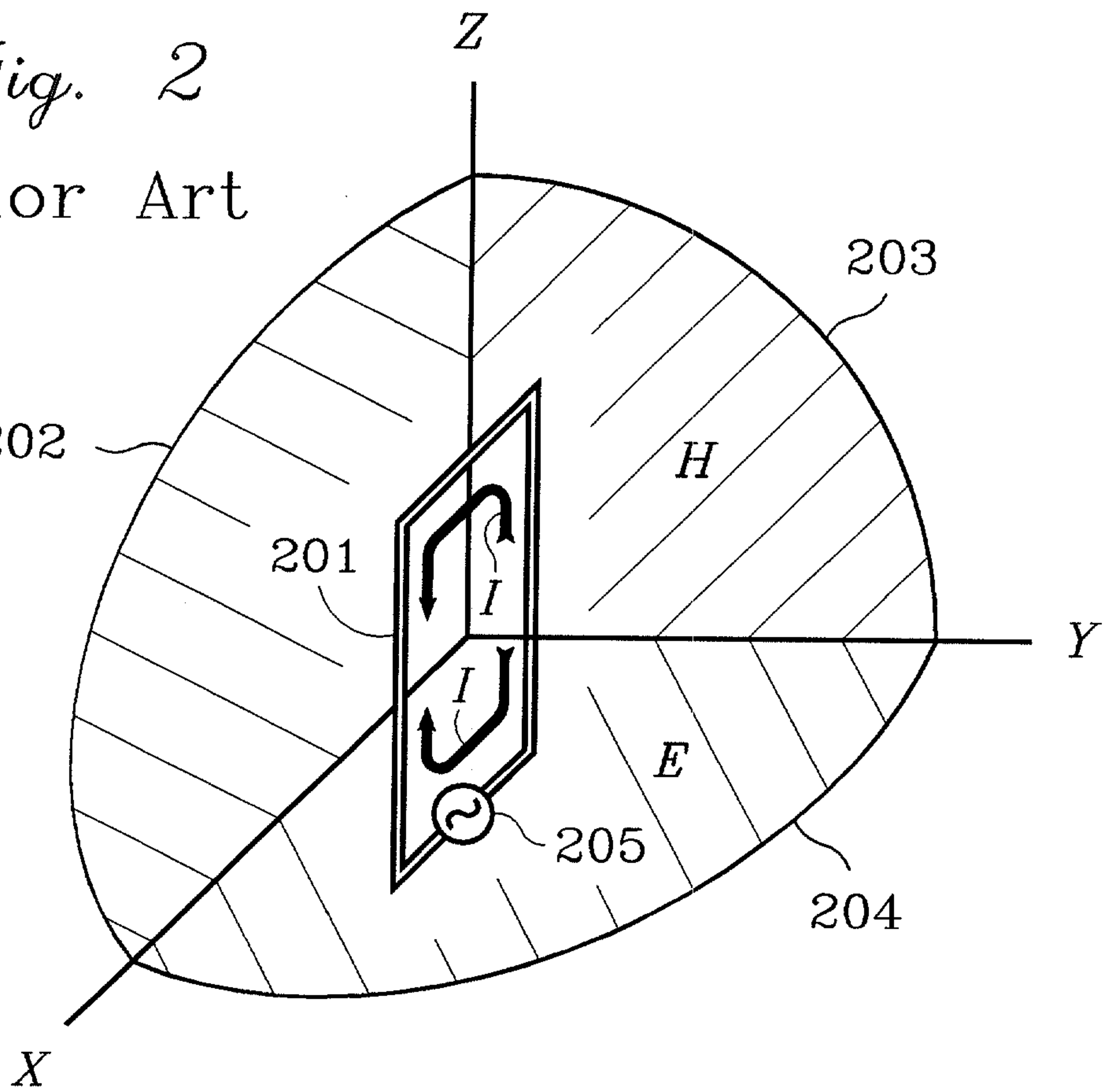


Fig. 3

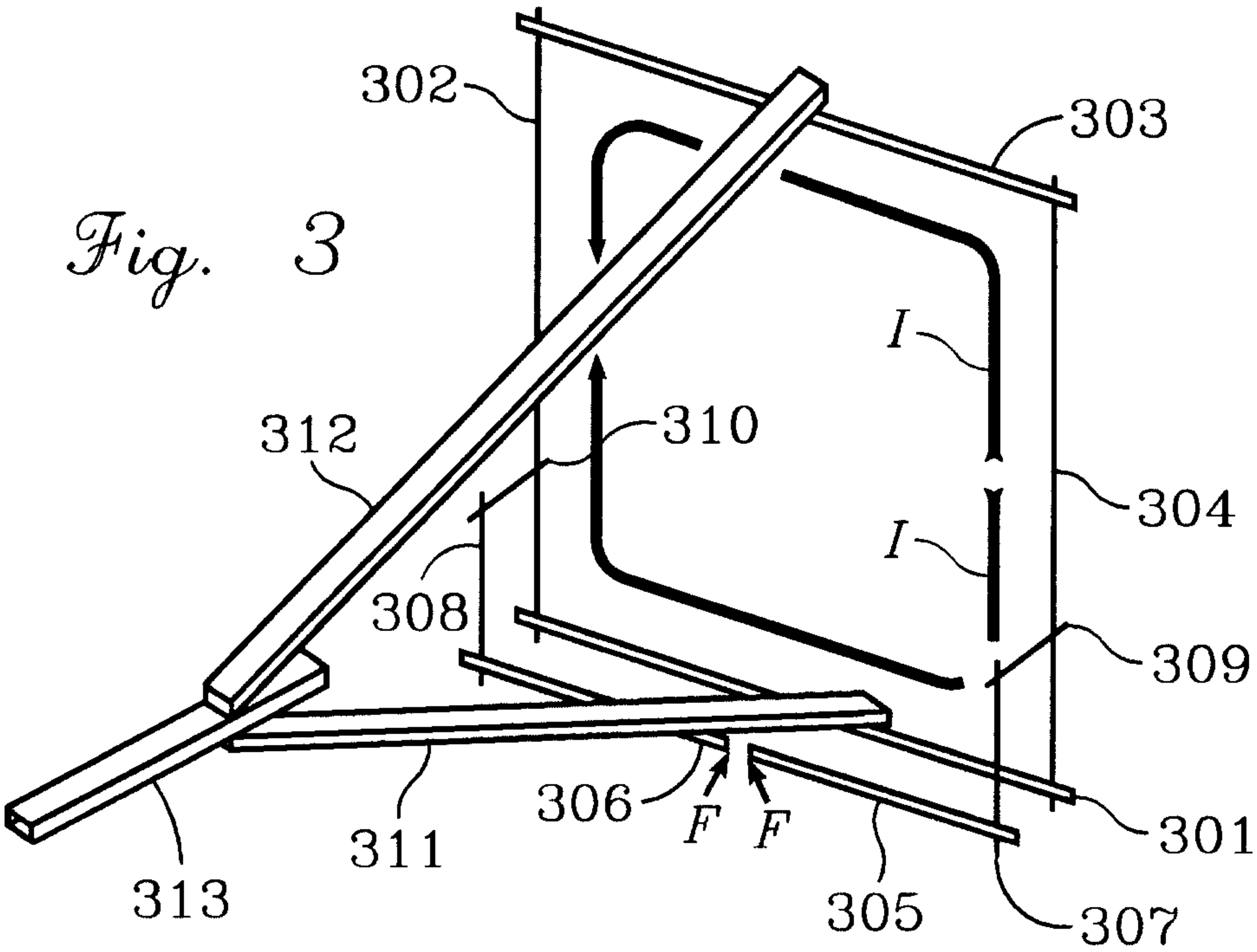

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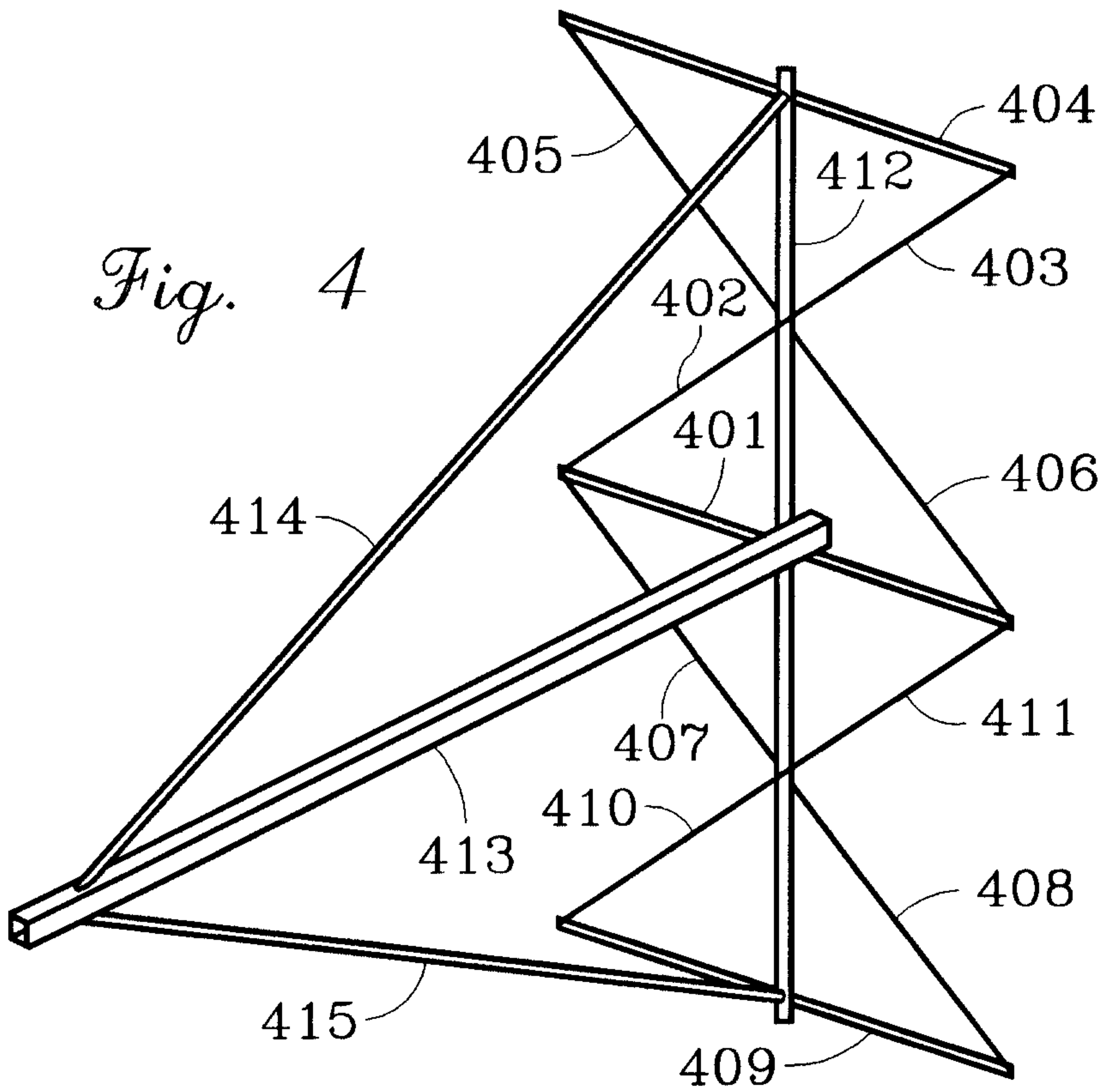
Fig. 4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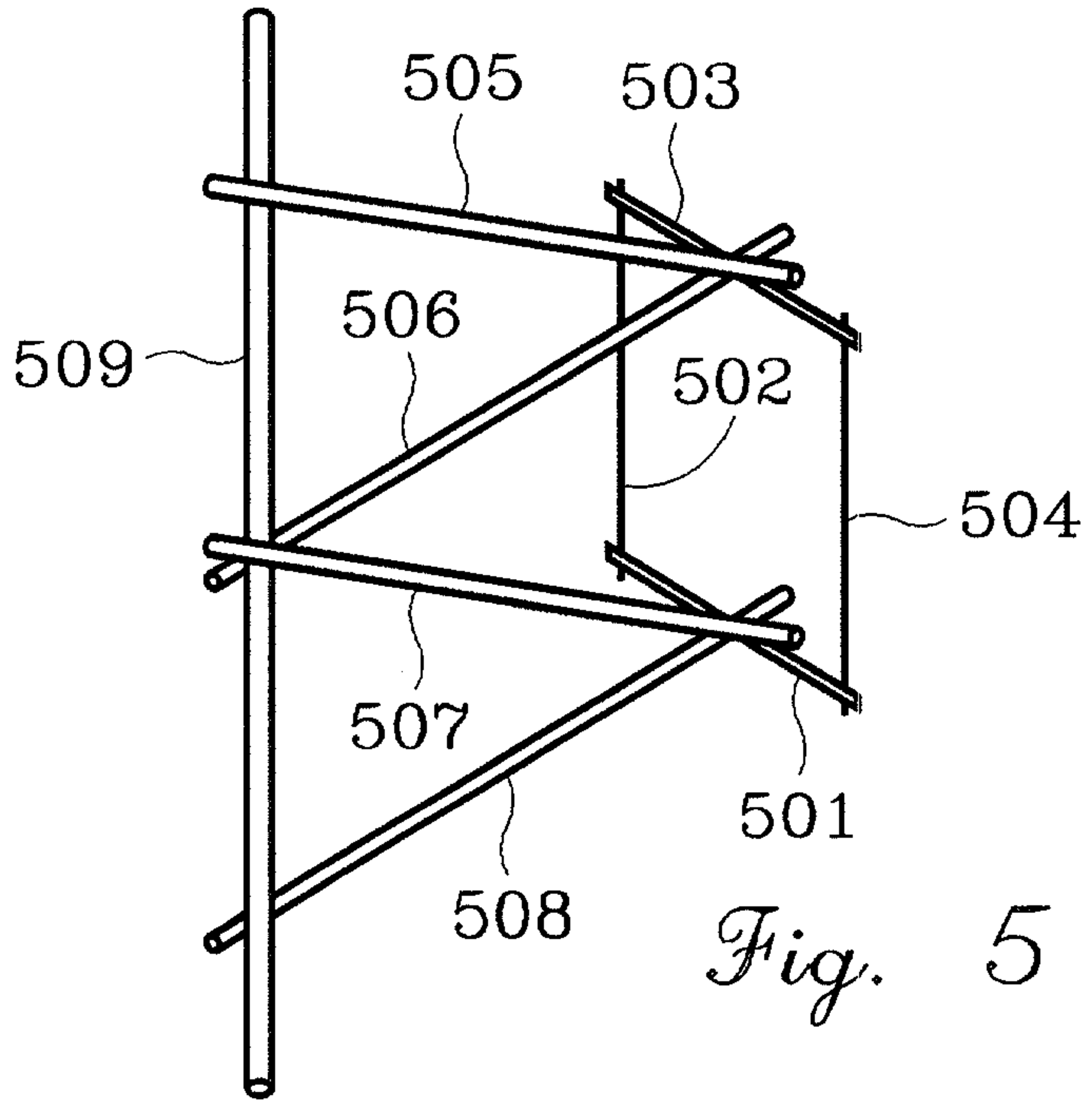
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Fig. 5

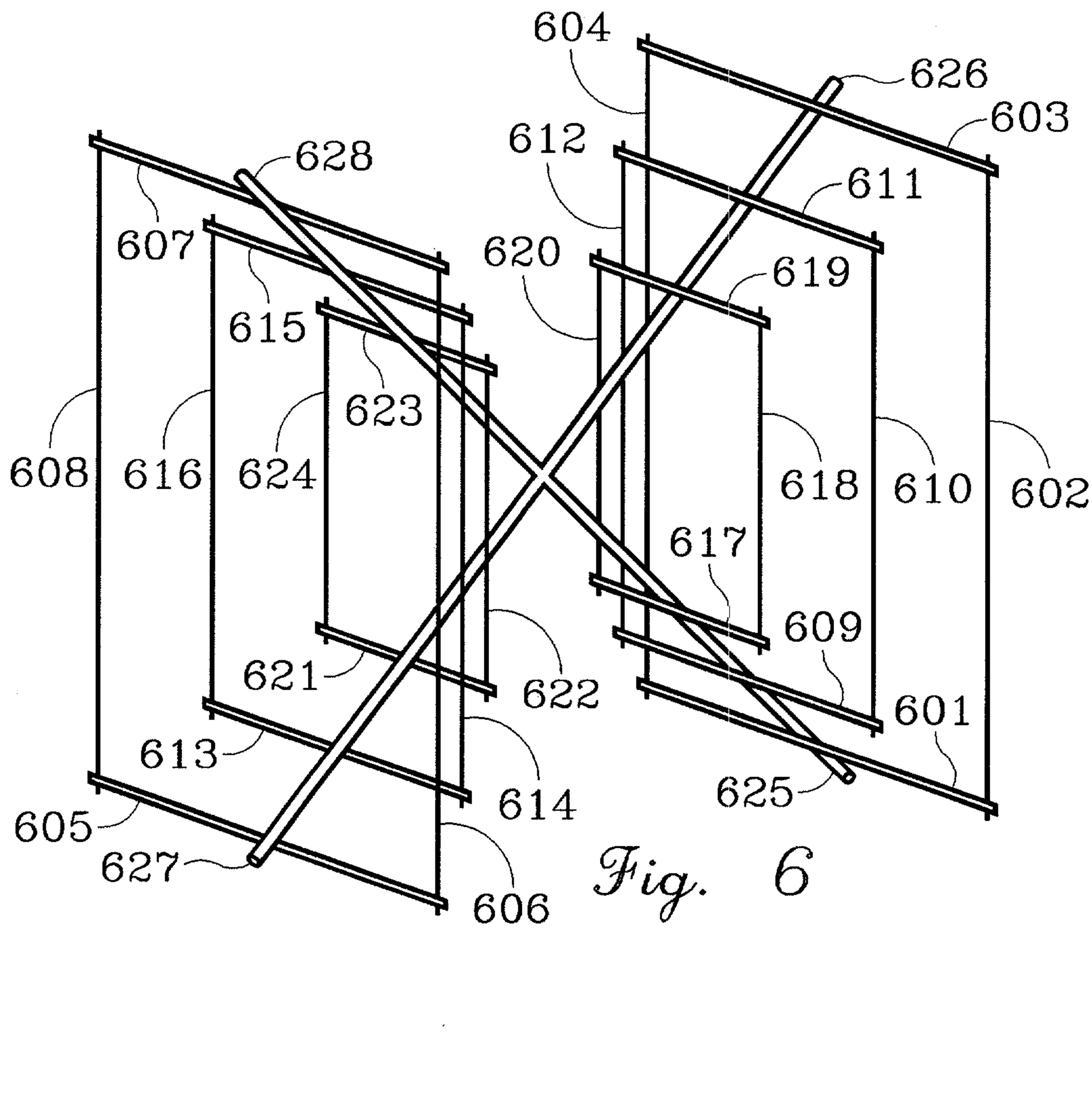
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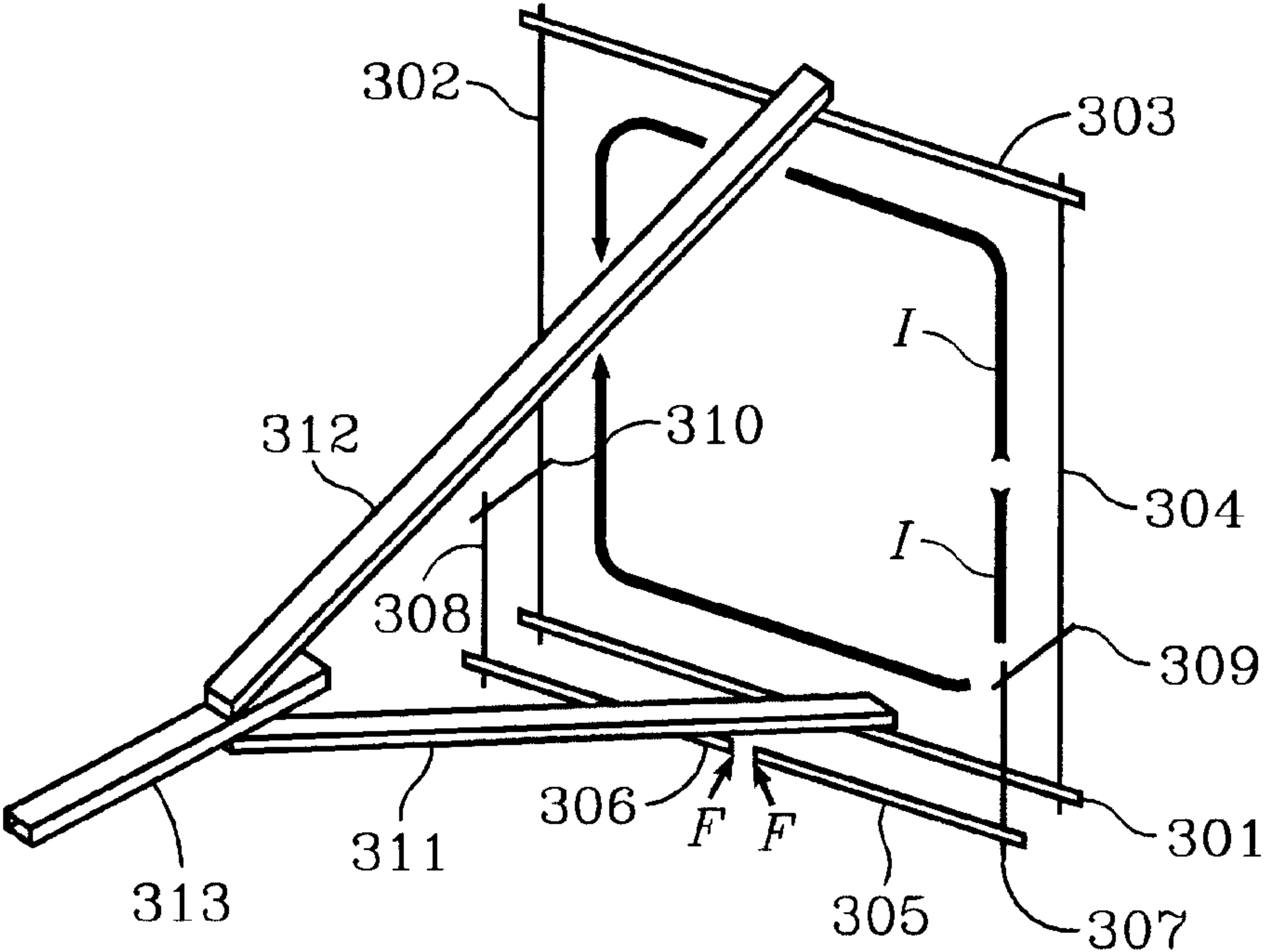
Fig. 6



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