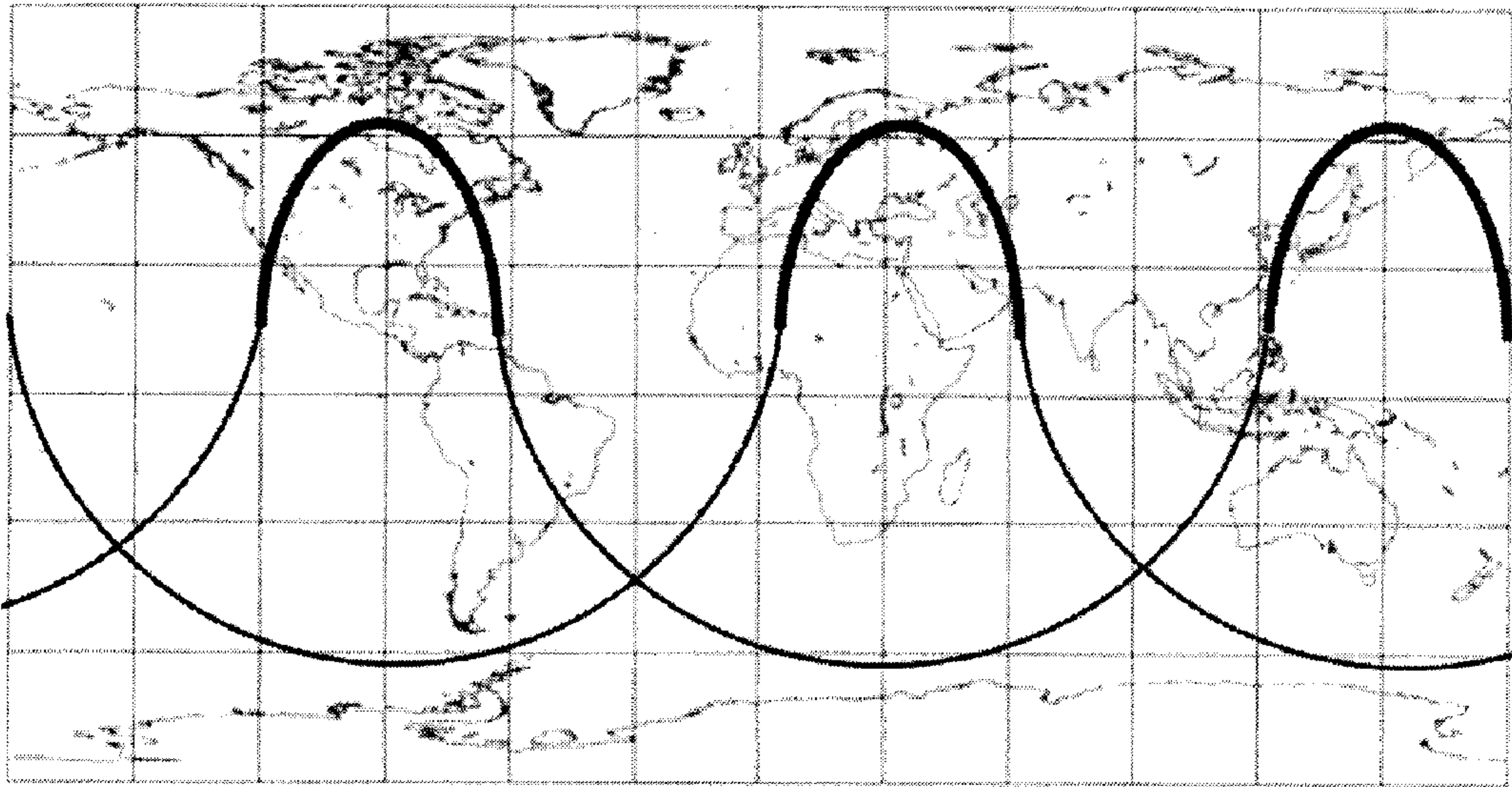




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(54) Titre : REPRODUCTION SYNTHETIQUE DE RESEAU A ARC ORBITAL DE SATELLITE GEOSTATIONNAIRE
AYANT DES PARAMETRES D'ORBITE ELLIPTIQUE PREFERES
(54) Title: SYNTHETICALLY RECREATING THE GEOSTATIONARY SATELLITE ORBITAL ARC ARRAY WITH
PREFERRED ELLIPTICAL ORBIT PARAMETERS



(57) **Abrégé/Abstract:**
System and method to utilize a plurality of satellites arrayed in inclined elliptical orbit arcs to provide synthetic geostationary communications with the earth, utilizing; overlapping active transmission portions of repeatable ground tracks, preferred orbital

(57) **Abrégé(suite)/Abstract(continued):**

separation or spacing to maximize communication link throughput performance and efficiency, preferred inclined elliptical orbit parameters, and methods to incrementally furnish supplemental capacity during peak demand or usage periods.

ABSTRACT

System and method to utilize a plurality of satellites arrayed in inclined elliptical orbit arcs to provide synthetic geostationary communications with the earth, utilizing; overlapping active transmission portions of repeatable ground tracks, preferred orbital separation or spacing to maximize communication link throughput performance and efficiency, preferred inclined elliptical orbit parameters, and methods to incrementally furnish supplemental capacity during peak demand or usage periods.

TITLE

Synthetically recreating the geostationary satellite orbital arc array with preferred elliptical orbit parameters

TECHNICAL FIELD

This invention discloses the use of elliptical orbits for satellite telecommunication and broadcasting, and ways to maximize efficiency of associated communication networks.

DESCRIPTION

Two new quasi-geostationary satellite orbit operating regions are invented and described herein. The geosynchronous & geostationary orbit (GSO) arc that is currently utilized by communications satellites – commonly referred to as the Clarke Belt after its inventor Sir Arthur C. Clarke – is recreated in alternate ideal locations in the sky by utilizing enhanced inclined elliptical satellite orbits to create a plurality of fixed repeatable ground tracks with apogee peaks in the northern and southern hemispheres spaced optimally to address current overcrowding and future communication supply shortfalls, and to incrementally furnish supplemental in-orbit satellite capacity at local daypart periods when fluctuations in demand peaks.

This invention specifies a system and methods to incrementally add additional quantum of transmission data throughput using preferred angular separation orbital spacing parameters; preferred orbit parameters, and the use additional overlapping ground tracks to achieve higher data throughput to enable a constellation array of many satellites that are utilized to create essentially two additional Clarke Belt GSO arcs (dubbed 'Clarke Belt 2.0'); enabling more than double the total amount of usable spectrum per degree of longitude than previously disclosed methods. The resulting number of satellites able to be operated coincidentally in the new Clarke Belt 2.0 orbit space significantly surpasses the current total quantum, effective transmission capacity and throughput arising from the inherent 180 satellites per spectrum band limitation of the Clarke Belt GSO arc. An arrayed constellation of satellites employing multiple spectrum bands can utilize the aforementioned preferred embodiments whilst maintaining the sufficient angular separation necessary for discrimination of efficient satellite communication links. This invention also describes system and methods to incrementally supplement transmission data throughput to regions during peak usage periods, for example internet usage peaks, in dayparts to meet demand peaks.

The Clarke Belt geostationary satellite orbital arc is overcrowded and inefficient.

Geostationary satellite communications systems have been operating commercially for more than 4 decades. The original concept of geosynchronous repeaters in space, or geostationary satellites, was invented by Sir Arthur C. Clarke in 1945. The orbital arc

used for geosynchronous operation of geostationary communication and broadcasting satellites is commonly known as the "Clarke Belt". Orbital spectrum is a scarce and valuable resource which is closely governed by the countries operating satellites and by International Telecommunications Union (ITU) treaties and regulations. However, certain technical regulatory decisions were made long before newer technologies and widespread, critical and constant usage of communications was envisioned.

Satellite communications began almost 50 years ago by utilizing large parabolic communication antennas, known as 'dishes' for their shape, which were expensive due to their novelty, and their sheer parabolic dish size and resulting support frames and foundations. Large antennas provide higher gain because of more signal directivity. More antenna directivity allowed satellites to be placed in the more closely together in the Clarke Belt; to agreed limits where discrimination between operating satellites could be achieved with large dishes. That spacing, or orbital slot separation, generally agreed by the ITU's spacefaring nations was some 2 degrees of orbit separation.

Data usage per user has been doubling every 12-18 months. If satellites wish to reutilize and share the same, popular, spectrum bands, then a maximum of 180 orbital slots are derived from 2 degree separation (360 degrees around the equator divided by two). Historically, orbital slots over the most populated and prolific regions (those with highest Gross Domestic Product or 'GDP') developed quickly, to where the best orbital positions have now been occupied for many decades. Growth of the satellite communications industry forced additional spectrum band(s) to be utilized; which followed the same patterns of deployment and constriction over the highest GDP regions and continents, to the point where they too became overcrowded and limited growth.

Direct-To-Home and Direct Broadcast Satellite (DTH & DBS) TV distributors that sought to utilize smaller (cheaper) dishes for their service and successfully petitioned the ITU to enforce larger orbital slot separation; eventually settling on 9-10 degrees of orbital slot separation as sufficient to maximize reliable and efficient distribution of large amounts of data broadcasted to dish sizes of 45 to 70 cm.

Today's Clarke Belt is overcrowded and inefficient due to legacy networks, satellites may provide service for more than 20 years before retiring, and while newer and more

efficient technologies have been developed, it is difficult to maintain service to legacy customers during expensive upgrades and concurrent multi-generational service.

Non-geostationary satellite communication orbits allow growth.

Several non-geostationary satellite orbits have been invented to enable satellite communication. These include highly elliptical orbits (HEO) such as Molniya and Tundra; medium-earth and low-earth orbits (MEO or LEO) that may utilize polar or equatorial orbits, as well as others.

An inclined elliptical orbit may be created that mimics the geostationary orbit, and this style of orbit is utilized in this invention and the improvements herein which disclose; preferred elliptical orbit parameters, preferred embodiments to achieve more data throughput and efficient use of spectrum, and methods to incrementally add communications capacity timed to meet increased demand periods, as well as other preferred embodiments.

Nine (9) degree orbit spacing provides technical and economic benefits versus two (2) degree orbit spacing.

Orbital spacing of satellites is utilized to allow a valuable resource in space to be utilized by different entities. In order to balance the efficient use of space with maximizing the performance several advancements were discovered over the past few decades, which show several benefits over early satellite implementations. One of these was orbital spacing versus antenna size tradeoffs. Use of “two-degree spacing” in satellites is considerable less efficient than “nine-degree spacing”. As briefly discussed above, 2 degree spacing requires larger antennas (typically 2 metres or larger) for sufficient sensitivity and discrimination of adjacent satellites, in order to enable sharing of spectrum; which in-turn may increase remote user site costs and thereby reduce customer uptake, especially when compared to smaller antenna sizes of less than 1 metre.

Orbital slot spacing as commonly utilized and approved for DTH/DBS satellites (9-10 degrees) allows adjacent satellites to operate at higher transmit powers without interference to each other – as well as enabling utilization of smaller/lower cost user antenna diameters of 45 to 70 cm – the combination of which provides higher efficiency

from increased network throughput and overall economic benefits to consumers and DTH/DBS operators.

This invention describes improved parameters and preferred embodiments having technical and economic benefits. One of the benefits of this invention is the overall number of satellites allowed in the new orbit, each satellite further benefitting from better technical and economic parameters from increased spacing or separation.

Use of overlapping Ground Tracks surpasses the number of 'equivalent slots' available in the GSO Clarke Belt (480 vs 180).

This invention's preferred embodiment teaches a method to create sixteen overlapping ground tracks, eight overlapping ground tracks interleaved in each of the northern and southern hemisphere, where each ground track may produce 30 'equivalent slots' in each orbit ($16 \times 30 = 480$ slots). This preferred embodiment provides a number of other benefits and improved characteristics, including; increased overall data throughput, less costly user site antennae, less obtrusive and less costly user installations (wall or roof mounting versus concrete foundation), more pleasing aesthetics, and increased sales.

With this invention the GSO Clarke Belt's current 180×2 degree spacing orbital slots may be effectively synthetically recreated in two alternate regions of the sky each serving the northern and southern hemispheres with supplemental satellite capacity.

This invention teaches a method to develop 240 orbital slots in each hemisphere (480 worldwide), each slot having superior performance characteristics (~9 degree versus 2 degree spacing, improved path loss, less latency, etc.) when compared to GSO Clarke Belt parameters. Methods to minimize interference from conjunctions or crossovers of the repeating ground tracks are possible by choosing when satellites are placed into their orbits, thus phasing when satellites are active may be considered as well as other means to reduce overlap times or signal path interference from sharing common spectrum bands.

Threefold increase in data throughput accrues from this invention.

This invention provides more than twice the number of slots and can typically provide threefold increases in overall user data throughput accrues from having more satellites

(more than double), higher powered satellites, less overall adjacent satellite interference, less noise floor, improved user elevation angles from satellites operating more directly overhead (resulting in less signal attenuation and less line-of-sight view to satellite obstructions), more available satellites in view, more users sharing transmission capacity (user distribution contention smoothing), amongst other technical and economic benefits.

Preferred Elliptical Orbit Parameters have a number of other benefits.

The scarce number of unused available GSO orbit slots, along with a resulting increased and renewed interest in non-geostationary orbit (NGSO) orbits by low-earth-orbiting (LEO) systems, means the use of space for satellite communications is increasingly popular. Current ITU global regulatory submissions for LEO satellites far exceed 20,000 satellites; the U.S. FCC alone has received applications that exceed 10,000 LEO satellites. LEO NGSO communication satellites commonly operate at constant altitude heights between 800 and 1,400 km. Inclined elliptical satellite orbits (HEO orbits) that traverse through the 800-1,400 km altitudes to their perigee have potential for collisions with the more than 30,000 planned LEO NGSO satellites; or otherwise may force HEO operators to manoeuvre satellites with rockets to avoid collisions, or affix protective shielding. Adding rockets or shielding capabilities to inclined elliptical orbit satellites increases their mass and expense to launch.

Space debris from earlier LEO satellite collisions and anti-satellite missile tests have created over 10,000 pieces of cataloged space debris that NASA tracks in the 800 km to 1,000 km orbit height, as well as an estimated 1 million additional particles too small to track at ever-spreading orbit heights, but still deadly to satellites. Orbits which have perigee heights above 1,500 km avoid the regions of space where collisions are likely.

Higher perigee is achieved by reducing the orbit eccentricity. Elevating perigee height also has a benefit of less orbital drag and therefore extends satellite lifetimes or reduces mass requirements from less fuel, and subsequently lowers satellite launch costs if less mass. Furthermore, elliptical orbits with less eccentricity (essentially flatter) provide additional benefits, as reducing the apogee height provides improved technical parameters accrued from lower height/shorter path to satellites; specifically reducing apogee heights generates less path loss attenuation and less round-trip latency.

Another benefit from this invention specifies preferred elliptical orbit height parameters of 1,525 km; although other perigee height values above 1,500 km are possible and still preferred.

Less eccentricity is another specified preferred embodiment; as an increased perigee altitude above 1,500 km height reduces potential collisions and reduces drag (reduced drag generates longer satellite lifetimes and less launch weight/mass); and lower apogee delivers improved technical performance of less latency and less path loss.

Ability to add incremental capacity to meet demand peaks is another benefit.

Internet usage peak demands may occur in response to the number of users at peak times, or from the nature of the traffic being communicated, or a combination of the two. Consumption of video related traffic may constitute half of the typical traffic of internet data distributed, the majority of which are consumed during evenings. Internet traffic loads may vary considerably throughout the day; and at peak times may be triple or quadruple off-peak times. Additional capacity may also be sought for other business purposes which may include but are not limited to; off-peak data store-and-forward, business users seeking video connectivity or broadcasting, mobile cellphone or data consumption, live sporting events, point-of-sale and banking transactions; or consumer social media and web browsing – amongst others.

Another benefit of this invention is the ability to incrementally add satellite distribution capacity specifically timed at a repeatable time of day around the world to meet user demand peak(s). This invention teaches a system and method to provide incremental satellite capacity timed to supplement capacity at a repeatable portion of day; known as a 'daypart'. By utilizing any satellite orbit having a repeatable ground track that occurs in the same portion of the sky overhead each day, incremental capacity can be provided to be in the active arc area for transmission at specific dayparts by utilizing several means that are disclosed herein.

A preferred embodiment to this invention is the ability to add incremental capacity in chosen dayparts by adding capacity to any specified orbit. The means to increment capacity may include the following methods to cause additional capacity to be timed to coincide with any desired time periods requiring additional capacity, including; causing

higher capacity satellites to coincide with the desired periods, or causing additional single or multiple satellites to be interspersed to arrive coincident with the desired periods. Higher capacity satellites may be formed by several methods, including; employing additional spectrum bands, higher power satellites, utilizing larger antennas on satellites, employing more spectrum or frequency reuse, spot-beam transmissions, higher-order modulation efficiencies, on-board signal processing, or other techniques developed to cause more capacity over a satellite communications link.

There are additional methods specified to utilize the inclined elliptical orbits.

There are other benefits of the invention and preferred embodiments disclosed herein. A number of invented methods are disclosed in the claims and description; which disclose certain inventions and specified combinations of methods to improve use of elliptical orbits herein. These inventions generally disclose, but are not limited to; single-hop hemispheric communication links and applications, communication link improvements, methods to mitigate and improve satellite positioning and control effects generally including artificial intelligence, providing secure communications during the portion of the non-active arc approaching perigee where higher speed orbit transiting occurs, and methods to maintain link connection during handoffs.

DETAILED DESCRIPTION

BACKGROUND

Satellites situated in geostationary orbits (GSO) remain essentially at the same position relative to the earth. Geosynchronous orbits require specified parameters at 42,164 km from the center of the earth (35,786 km above sea level) and positioned above the equator at 0° inclination to make this work, therefore there is only one orbital track (orbit) which can be utilized for GSO geosynchronous satellite operation. Within the GSO orbit there are a finite and small number of available geostationary slots. In recent years, global demand for delivery and consumption of data has been doubling every two years, and demand for satellite capacity and bandwidth increases in line with the demand for data.

The parameters governing utilization of GSO were globally adopted when commercial satellites were established during the 1970's, which allowed for the use of large receiving dishes on the ground. That created an environment which allows multiple slots within the single GSO ground track orbit, each slot having approximately 2 degrees of separation in the GSO orbital arc in order to enable larger directional antennas to communicate with a minimum of electronic interference; while later on approximately 9 degrees of orbital spacing was mandated and utilized for higher powered satellites to communicate with smaller antennas. The GSO ring around the equator hence has a total of 180 operational orbit slots (360 degrees divided by 2 degree separation spacing) for large antenna operation, or 40 slots (360 degrees divided by 9 degree separation spacing) for small antenna operation due to wider aperture beamwidth of small antennas.

There are a scarce number of geosynchronous slots that remain available for development – particularly overhead of the most populous regions of the earth which were developed first.

The present invention teaches a synthetic array of essentially geostationary satellites which address the scarcity problem, and provides two totally new dimensions or regions of the sky for several hundred satellites in new equivalent orbital slots. These new slots have many of the advantages of geostationary orbits; however, due to their closer

proximity to the earth and higher elevation angles for communication, among others, they provide superior communications link performance.

A new GSO-like synthetic space called the Clarke Belt 2.0 is disclosed according to the present invention. This provides new orbital slot real estate in the satellite sector.

The newly created orbital slot space can include a number of satellites in elliptical orbits, which satellites are active during an “active arc” occurring during their apogee portions. Multiple overlapping ground tracks may be created, each with multiple satellites placed in each orbit to trace the same ground track, where multiple satellites can operate one after the other in an orbit appearing as a “cars on a freeway” which may bunch up or spread out according to their speed and the ebb and flow of traffic. The same number of satellites, at least one, is in the active arc apogee portions at any point in time.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the invention will be described in detail with reference to the accompanying drawings, wherein:

FIG. 1 shows the orbits of the satellite array of the present application;

FIG. 2 shows a typical 24 hour repeating ground track, consisting of three 8 hour repeating ground track loops, each with a bolded active arc;

FIG. 3 shows multiple overlapping ground track loops equally spaced 15 degrees of longitude apart in the northern hemisphere, and FIG. 4 shows multiple overlapping ground track loops equally spaced 15 degrees of longitude apart in both the northern and southern hemispheres;

FIG. 5 shows a preferred embodiment displaying 8 ground tracks in the northern hemisphere and 2 ground tracks in the southern hemisphere, mimicing the population ratio of the northern versus southern hemisphere, and locating southern ground tracks over populated regions; and

FIG. 6 shows multiple satellites optimally arrayed in one of the ground track loops of the preferred embodiment.

FIG. 7 shows multiple overlapping ground tracks produced by interleaving 8 ground tracks in the northern hemisphere with apogee peaks every 15 degrees of longitude; indicating points of orbit conjunction.

DETAILED DESCRIPTION:

FIG. 1 shows the orbits of the satellite array of the present application. Each of a number of satellites is placed into elliptical orbits of a special type. The preferred orbits are inclined at inclination of around 63 degrees, e.g., 63.435 degrees. The satellites are in posigrade elliptical orbits having three revolutions per sidereal day.

The argument of perigee refers to the location of the lowest altitude portion of the orbit around the orbit from the point in the orbit where the orbiting satellite crosses the equator in a northward direction. The orbits preferably have an argument of perigee near 270 or 90 degrees, which has the effect of placing the apogee or highest point of the orbit over the northern-most or southern-most portion of the orbit respectively.

The orbits have an eccentricity of around 0.60 to 0.62, e.g., 0.61.

The satellites may also have an apogee altitude of approximately 26,250 km, perigee altitude of approximately 1,525 km, argument of perigee at or near 270 or 90 degrees, eccentricity of about 0.61, altitude over the equator of approximately 5400 km, altitude at start and end of the active arcs of around 12,000 km, approximately 25 degrees (north or south) latitude at start and end of the active arcs, and nominal latitude of 63.435 degrees. The orbit semi major axis is approximately 20,150 km.

Orbits having an integer number of daily revolutions have a ground track that passes over the same point(s) on the earth every (sidereal) day. Such ground tracks are referred to in this specification as repeating ground tracks.

The satellites are only active during part of their time of orbit. The time and positions when the satellites are active is referred to as active arcs. The active arcs are defined to

be centred on the orbital apogee peak, where the satellites are higher and travel most slowly to maximize the time that a satellite spends in the active arc. In this embodiment, each earth communicating satellite remains in each active arc for around 5.5 hours. After leaving the active arc, each earth communicating satellite becomes inactive and non-emitting, and spends 2.5 hours transiting to its next active arc whose apogee peak is 120 degrees of longitude to the west. The satellite then enters another active arc and begins communications again. This means that each satellite is active for $5.5/(5.5+2.5) \approx 70\%$ of the time.

Each of the satellites includes communication equipment which communicates with corresponding communication equipment located on the earth. Therefore, the satellites may communicate with various points on the earth, or each other, or other satellites, or mobile objects.

Near apogee, where the satellite's progress slows, its motion almost matches the rotational speed of the earth. Therefore the earth-communicating satellites in the active arcs will therefore appear to move very slowly, or linger overtop the earth. Since the argument of perigees are at the southern-most or northern-most ends of the orbits, the active arcs straddle the apogees, and the corresponding active portions of the ground tracks, are hence displaced at a large angle to the North or South respectively from the equator and the geostationary orbit.

A first set of satellites have apogees in the Northern Hemisphere forming the space. Those satellites are also shown in the ground track map of FIG. 2, with their respective apogees shown being bolded in FIG. 2. A second set of satellites has apogees in the Southern Hemisphere forming the space.

FIG. 2 shows the active parts of the arc in bold. While the satellites are in these active parts of the arc, they have a similar rotational rate relative to the earth, and therefore appear to move very little relative to the earth. The space in which these apogees may occur moves at a similar rotational rate to the Earth, thus becoming the "synthetic geostationary space", in which active arcs derived from the synthetic geostationary orbits lay.

The synthetic space may therefore include a number of satellites, each of which is in an inclined elliptical orbit with its apogee over a Hemisphere, either the Northern or Southern Hemisphere.

In the embodiment disclosed herein, the satellite is active over substantially 5.5 hours out of every 8 hour orbit, this orbit repeating itself 3 times per day (~24 hour sidereal day) and defining a repeating ground track. Generally, each of the satellites is active for substantially 70 percent of the time it is in orbit, but more generally can be active within 60 and 80 percent of the time that it is in orbit.

Several satellites may occupy the same ground track. The satellites in the single ground track are minimally timed so that as soon as one satellite leaves each active arc of the ground track, another enters that active arc and provides effectively continuous service. Each ground track has three active arcs around the earth, and, if continuous coverage is desired, enough satellites are placed in the ground track, spaced evenly in time, so that there is always one satellite in each active arc per system. For example, FIG. 6 shows 14 satellites in each repeating ground track loop. The active arc includes the top part of the curve. FIG. 6 shows how the satellites bunch up in this area as they slow down, and that there are relatively fewer satellites in the other, non-active, areas. The satellites are preferably placed within the active arc in a way such that there is at least one satellite in each active arc per system at all times, but preferably more than one. The active arcs in the Southern Hemisphere could be the inverse of the Northern Hemisphere active arcs.

With these parameters, a ground track with three active arcs provides coverage of substantially three times sixty degrees of longitude, or 180 degrees of longitude. A second ground track may be interleaved to create a second set of active arcs in the Northern Hemisphere to thereby provide another 180 degrees of occupied longitude. A maximum of 36 active arc apogee peaks (12 repeating ground tracks) can be overlapped and developed in each hemisphere whilst providing a desired level of discrimination between satellites. If less is required the active arcs may be placed at any preferred longitudes to maximize the viewing angles to continental landmass areas. In this preferred embodiment 8 overlapping repeating ground tracks are disclosed, each having apogee peaks occurring approximately every 15 degrees of longitude.

Since the satellites are only communicating near apogee in their active arcs, these create the synthetic orbit space. The satellites actually trace a complete path which is not shown in FIG. 1. However, the space is formed only by the active arcs of the satellites. The satellites actually travel in other positions besides these active arcs, but communicate only within these active arcs.

Multiple earth communicating satellite systems may use the same active arcs disclosed above, to place its earth communicating satellites in the same ground tracks as above. However, this system times the entry of its satellites to differ from those of other systems by at least t_θ , where θ is the minimum separation desired in the active arc occurring at apogee, and t_Δ is the time necessary for a satellite to move that distance at that location.

Preferred slot parameters may include relationships between Desired Orbital Separation, Relative Mean Anomaly, and Relative Right Ascension. Where:

- RMA is relative mean anomaly or Mean Anomaly difference between two satellites in degrees relative to a common epoch (reference time), as measured in each respective orbit,
- Relative Right Ascension is the difference in degrees between the RAANs of two orbits,
- T_{ta} is the time required to move a desired number of degrees true anomaly at apogee in seconds,
- P is satellite orbital Period in seconds

The preferred mathematical relationships between Right Ascension of the Ascending Node and Mean Anomaly for satellites flying in the same ground track may be specified, but separated by a minimum of θ degrees earth central angle. Each entry time differing from its neighbor by t_θ constitutes a slot in the active arc. Each satellite in each active arc occupies one slot in that arc. A “protected” interval may exist around the satellite which travels with the satellite. In a geostationary orbit, a slot is defined by the longitude of the point on the earth under it. In this synthetic geostationary orbit, a slot is defined as an active arc entry time stated for a specified epoch day. Ground tracks and active arcs may be created, with one satellite in each active arc at all desired times.

The orbital parameters described above may be varied somewhat while still preserving the characteristic of stationary active arcs over the northern or southern hemisphere. However, all satellites to be slotted together into active arcs in a coordinated fashion using this scheme may agree to use at least the same Mean Motion, eccentricity, inclination, argument of perigee, and ground track. The right ascension of the ascending node and mean anomaly of each satellite are preferably also adjusted together in order to place the satellite on the specified ground track at the satellite's specified time of active arc entry. This yields a coordinated motion among all such satellites where minimum separation criteria among them can be guaranteed.

Orbital parameters are adjusted to create ground tracks that repeat daily. In this preferred embodiment, each ground track has three active arcs in the Northern Hemisphere using orbital arguments of perigee of around 270 degrees. Each active arc spans over 50 degrees of longitude at the highest portion of the orbit. All three active arcs in a ground track therefore occupy over 150 degrees of longitude.

A second ground track interleaved with the first creates a second set of active arcs in the Northern Hemisphere accounting for another 150 degrees of occupied longitude, for a total of 300 degrees of longitude occupied by active arcs. Additional ground tracks can be equally interspersed, up to a practical maximum where active arcs are spaced each 10 degrees of longitude, or 12 ground tracks in each hemisphere. In this preferred embodiment the optimal spacing is 8 ground tracks in each hemisphere; creating 24 repeating ground track loops or active arcs, spaced each 15 degrees of longitude in each hemisphere. Ground tracks may be optimally spaced so as to maintain a minimum separation between all active arcs while providing optimum position and coverage characteristics for the active arcs. Active arcs may also be freely placed on any line of longitude to maximize viewing angles to desired service areas.

This process is repeated in the Southern Hemisphere using orbital arguments of perigee of around 90 degrees.

Since earth communicating satellites using these active arcs are in orbit at over 12,000 to over 26,000 km, from these high vantage points each satellite in an active arc can see ground area encompassing several active arcs, or indeed several continents. FIG.

1, for example, shows a view from space centred over North America with many satellites in northern hemisphere orbits, with their apogee peaks overhead. An inverse, or upside down, orbits would be created if southern hemisphere orbits were depicted.

In order to place multiple satellites onto the same ground track passing at spaced time intervals, the planes of the orbit of following satellites may be rotated about the earth's axis by the amount and in the direction the earth has rotated in the interval between the time(s) the satellites pass over a given point. Larger time intervals between satellites in a ground track may cause more orbital rotation of the following satellite about the earth's axis to keep the satellite over the same ground track. This angle, when measured relative to a celestial reference point, e.g., the position of the sun against the stars at the time of the Vernal Equinox, is known as the orbit's right ascension of the ascending node (RAAN). If all satellites moved in the same orbit, rather than orbits that have been adjusted for earth rotation, following satellites would travel in ground tracks further to the west of those of the preceding satellite, since the surface of the earth is constantly moving around to the east relative to the stars. Hence to follow a common ground track and share active arcs, each satellite should occupy its own orbit having its own RAAN.

FIG. 6 illustrates the satellites occupying successive slots in one active arc and the separate orbits and relative positions in orbits which allow each satellite to follow the active arc properly.

Spacing in space can be assured by ensuring a constant separation of the points in the ground tracks under each satellite, and if necessary adjusting orbits to ensure differing altitudes at ground track crossings. Satellites in adjacent ground tracks may be phased or timed to stagger their distance from adjacent ground tracks. FIG.9 illustrates ground track orbit crossover points, known as conjunctions, for overlapping ground tracks in the preferred embodiment of 8 ground track loops in the northern hemisphere. By timing the satellites in each adjacent ground track properly, for example every other ground track equally staggered, conjunctions may be completely avoided and desired 9 degree angular separation between satellites may be maintained or optimized.

FIG. 4 illustrates a possible configuration of 16 ground tracks, or 48 repeating ground track loops, over the earth. FIG. 5 shows a preferred embodiment of 8 northern and 2

southern ground tracks, mimicking the ratio of population in the northern and southern hemispheres.

FIG. 6 shows the satellites following behind each other in the paths illustrated in these figures, while maintaining a separation of at least nine degrees earth central angle from all other satellites. The active portion of the ground track occurs in the higher, flattened portion of the satellite paths shown in FIG. 6. These portions are slow moving and essentially geo-synchronous creating a “synthetic geostationary” arrangement for placing earth communicating satellites.

If the satellites are spaced so as to maintain at least, for example, nine-degree intervals at apogee within the active arc, on the order of 14 satellites can be placed in each ground track, comprising 10 in each of three active arcs and 4 in transit between active arcs in each ground track. Each satellite travels in its own orbit. The similar orbits differ only by their RAAN and mean anomaly (MA), whereby in this example the RAAN of the orbit of each immediately following satellite in the ground track is increased over that of the preceding satellite and its mean anomaly adjusted to be less than the preceding satellite.

Since this invention discloses 16 ground tracks, each with three active arcs, this invention can accommodate $16 \text{ ground tracks} \times 10 \text{ satellites per active arc} \times 3 \text{ active arcs per ground track} = 480$ equivalent active arc satellite slots. FIG. 6 illustrates an active arc occupied with satellites placed at approximately 9-degree spacing.

In this preferred embodiment, the apogee of the satellites lays at around 26,000 kilometers above the surface of the earth, or around three-quarters the altitude of satellites in the geostationary orbit. The lower 26,000 kilometer apogee altitude of this embodiment leads to savings in satellite costs, since the shorter path to and from the satellite yields less path loss, on the order of 7dB less than that of a geostationary satellite. The consequent reduced power requirements for a given link translate into savings in satellite weight and cost for a given capability. In addition, the orbit used in this preferred implementation requires less than half the launch energy required for launch into the geostationary orbit, yielding additional savings. These savings offset the costs of satellite time spent outside of active arcs.

The chosen active arc regions minimally deliver a 25 degree separation between the active arcs and the geostationary Clarke Belt arc. However, other degrees of separations can also be used, simply by setting the amount of time or length of active arc of communicating with the satellites.

Different numbers of satellites may be used, as described herein. In an embodiment, the satellites form two different ground tracks in each of the Hemispheres. Each of the ground tracks has three distinct active arcs. FIG. 2 shows one ground track in the Northern Hemisphere, with three active arcs. These ground tracks can be populated by satellites. In this embodiment, the peak of the active arcs, or apogees, is at 63.4 degrees latitude.

One advantage of this system is that this may avoid interference between the synthetic geostationary inclined elliptical orbit satellites, and the GSO Clarke Belt ring of satellites. The disclosed system may have more than 25 degrees of angular separation between the satellites and the GSO ring.

Other modifications of these parameters can of course be used. While the above has described the peak of the active arcs being at 63.4 degrees, the minimum latitude for the active portions of the active arcs is about 25 degrees latitude, on either side of the apogee. Generally anything greater than 25 degrees, and more generally anything greater than 30 degrees latitude, may be preferred.

Several independent system operators can use the slowly moving, active, satellites in each active arc. This may provide a total of 30 slots for the three active arcs in each one ground track. With 42 satellites in a single ground track, continuous coverage may be provided underneath all three active arcs. This system may have multiple advantages. By making the satellites active during only part of their orbits, the satellites create no interference with each other or with the GSO. The satellites are also much lower in altitude than the geo satellites. Hence latency may be better than geos, the satellites may be smaller, less expensive, require a smaller antenna, are less expensive to launch and allow more frequency reuse. The apogees at the active arcs may be placed at specific longitudes to concentrate the capacity over land masses. These satellites may

use C, X, Ku, Ka and Q/V bands, but may also use the L, S Bands, or other bands allowed by regulation.

An explanation of the constellation parameters follows:

- a. Mean Motion: The number of revolutions around the earth the satellite makes in 1 day. An integer value of mean motion ensures that the satellite will repeat the same ground track each day. Since we want all satellites to follow a repeating ground track, and wanted each satellite to visit no more than 3 active arcs, we selected an integer mean motion, rather than a rational mean motion, which would have yielded repeating ground tracks at intervals longer than one day. A mean motion of 4 yields 4 active arcs per ground track and active arcs that are too broad to maintain the regional geographic coverage that we desired. A mean motion of 2 yields 2 active arcs per ground track, and very narrow active arcs. Slotting here is less feasible, since positions on the active arc are not well separated in angle. Also, its apogee altitude is high, being around 38,500 kilometers, leading to high latency. This is the well-known Molniya orbit.
- b. Inclination: 63.435 degrees. This figure prevents the line of apsides, the line connecting the apogee and perigee, from rotating around the orbit, moving the apogee southward toward the equator. If the inclination is higher, the line of apsides will rotate in a direction opposite to the direction of satellite motion. If lower, the line of apsides will rotate around the orbit in the same direction as satellite motion.
- c. Eccentricity 0.61. This value, when combined with the necessary mean motion, yields an apogee of 26,400 kilometers, and a perigee of 1,525 kilometers. While there is a small amount of drag at that perigee, orbit lifetimes are expected to be into the tens of years, since most of the orbit is spent much higher.

A lower eccentricity will yield lower apogees, higher perigees and even less atmospheric drag and LEO orbit intersection, but slightly lower declinations (angle above the equator from the center of the earth) for the lowest part of the active

arcs. Coverage area will be also reduced, due to lower operational satellite altitudes at active arc end points.

- d. Argument of Perigee: 270 degrees for northern ground tracks and 90 degrees for southern ground tracks. These values are important as they determine where the apogees are, where satellite motion is slowest. These figures place the apogees at the furthest angles in declination from the equator, and keep the active arcs, which span 216 degrees of Mean Anomaly, well separated from the equatorial arc. As the Argument of Perigee departs from these values, the ends of the active arcs will move toward the equator. Some slight variation in argument of perigee from the cited value, on the order of one degree, might be desirable to ensure good satellite spacing at orbit crossings. Otherwise little flexibility exists in these numbers.
- e. Longitude of Apogees: This measure specifies where the peaks of the active arcs are located over the surface of the earth in coordinates relative to the rotating earth. For a Mean Motion of 3, a satellite's ground track will pass through three apogee longitudes, spaced 120 degrees from each other in longitude. Therefore, for a given ground track, specifying one Longitude of Apogee specifies the other two as well. For convenience therefore, specifying the location of the active arcs in the Americas region from 0 degrees West Longitude to 120 degrees West Longitude is sufficient to locate a ground track in any Longitude orientation. A given ground track may have any Longitude of Apogee in this 0-120 degree range. Good coverage of important markets may be an important criterion for selecting the locations of the Longitude of Apogees. The second ground track should have an Apogee of Longitude that places the active arcs between those of the first, without crossing and maintaining a preferred separation from those of the first, depending on desired coverage versus active arc separations.
- f. Active Arc Span: 2 hours and 40 minutes (or 120 degrees of Mean Anomaly) to each side of apogee, plus ~8 minutes per side for housekeeping, and switchover. The ratio of active satellites to total satellites per ground track per system determines this span. This choice derives from 4 active satellites and 6 total

satellites per ground track. It is however possible to design an arrangement using 3 active arcs one active satellite per arc, and 4 total satellites rather than 6. In this case the active arcs extend down to 28 degrees North declination at a minimum operational altitude of around 11,900 kilometers rather than the 17,500-18,000 kilometers of the present design. The satellites would have to cope with a greater variation in orbital altitude, but would be in operation for 75 percent of the time each. Coverage areas may suffer, since the extensions of the active arcs are at relatively low altitudes.

- g. Mean Anomaly at epoch: selected to place each satellite at an appropriate interval from its neighbor. The absolute number is not so important here as the relative MA. Absolute MA will determine when the satellite passes a point on the earth. Relative MA will determine the separations among satellites. Mean Anomaly spacing and minimum included zenith angles of the satellites are related.

Each Repeating Ground Track Loop (RGTL) is one active arc created over an 8 hour period on one ground track. Each ground track has three RGTLs. A communication system may provide substantial Northern Hemisphere coverage from 5 satellites in one Northern ground track, providing service from the equator northward everywhere under the active arc. At the worst-case Longitude exactly between active arcs, coverage from a single ground track exists north of 30 degrees North. Coverage of the Southern Hemisphere is similar, using a single Southern ground track. Global landmass coverage pole to equator to pole may be attained using two Northern and one Southern ground tracks and 15 satellites, with good RGTL placements. Full-time coverage from a ground track requires a minimum of 5 satellites per ground track.

Services offered by many prospective operators will concentrate on regional markets, or for example on markets primarily on land-masses. Ground track occupancy and visibility requirements can be reduced in that case. An operator seeking to service specific regions would place satellites in the ground tracks with active arcs serving those regions. A consortium of operators may share in the development, construction, and launch costs of satellites serving a particular ground track and its three RGTLs. Since

each satellite visits all active arcs daily in the ground track, a satellite loss is spread over three markets rather than one, and results in a 20% time-outage rather than a 100% outage. In-orbit sparing may be reduced (e.g., 1 for 5 rather than 1 for 1), and risk may be spread amongst operators (akin to an insurance pool), and losses are relieved.

FIG. 6 presents the number of satellite systems that can be accommodated in each ground track. Each satellite may belong to a different system. If a given system requires only one ground-track and places an active satellite in each of the three RGTLs, each ground track would, for example, accommodate 14 satellites per RGTL at a minimum required 9 degree zenith angle between satellites. The zenith angle may be measured from the surface of the earth. Each such system may moreover be viewed as equivalent to three regional systems, one per satellite per RGTL for distinct regional operations.

Although only a few embodiments have been disclosed in detail above, other modifications are possible.

All such modifications are intended to be encompassed within the following claims, in which:

CLAIMS

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method, comprising: forming a satellite system array which includes a plurality of satellites in multiple inclined elliptical orbits, said plurality of satellites or arrayed constellation of satellites in multiple orbit planes each communicating with the earth, or each other, or other satellites or mobile objects, may be formed as communication networks.
2. A method as in claim 1, further comprising defining selected parameters for the inclined elliptical orbit.
3. A method as in claim 2, wherein said selected parameters include eccentricity, inclination, longitude of apogee, RAAN ascending angle, and argument of perigee; and wherein the perigee and apogee altitudes, and eccentricity are specifically chosen to diminish chances of collision with other objects in space or to provide improved communication links.
4. A method as in claim 3, wherein said perigee altitudes are greater than 1,500 km and therefore do not intersect with the commonly utilized orbit altitudes of Low-Earth Orbiting (LEO) non-geostationary orbit (NGSO) satellite fleets, and said perigee altitudes additionally avoids the profusion of orbiting space debris in the 200 km to 1,000 km altitudes, thereby reducing chance of collisions with LEO satellites or debris.
5. A method as in claim 3, wherein said eccentricity is near 0.61 and apogee altitude around 26,400 km. Said apogee altitude providing certain technical benefits over GSO; said technical benefits having the desired effects of less latency, signal delay and path loss, and enhancing transmission link performance parameters.
6. A method as in claim 1, wherein each said inclined elliptical orbit(s) has a first portion during which the satellites have a speed which is similar to the speed of rotation of the earth and a second portion of the orbit(s) that is not similar to the rotation of the earth; wherein said orbit(s) are essentially geosynchronous during the first portion and produce a repeating ground track appearing to be nearly stationary moving slowly over the same spot(s) above the earth at a predictable time of day.

7. A method as in claim 6, wherein said ground tracks are created to deliver 3 repeating ground track loops at their apogee peaks, each having an 8 hour period with apogee peaks equally spaced at 120 degrees of longitude apart.
8. A method as in claim 1, wherein said enhanced multiple inclined orbits are utilized to create 16 or more overlapping repeating ground tracks, 8 or more in each of the northern and southern hemispheres having apogee peaks spaced equidistantly every 15 degrees of longitude or less.
9. A method as in claim 6, wherein said ground tracks may be created to deliver 4 or more repeating ground track loops, each having a less than 8 hour period with said apogee peaks equally spaced equal to or less than 90 degrees of longitude apart.
10. A method as in claim 7, wherein the longitudes of the apogee peak of the orbit(s) are chosen to be located at longitudes at, or nearby, the most densely populated global regions or those countries having the highest gross domestic product (GDP) in the appropriate hemisphere at each degree of longitude.
11. A method as in claim 1, wherein said constellation are only utilized when, or such that they do not present or provide harmful interference into the geostationary orbit (GSO) satellite arc.
12. A method as in claim 1, wherein said satellites are only utilized when, or timed such that, they do not present or provide harmful interference into other satellites utilizing the said inclined elliptical satellite orbits.
13. A method as in claim 12, wherein said constellation are formed by choosing orbit planes and the phasing of the satellite spacing selectively or actively, whereby it is possible to fashion the overlapping repeating ground tracks so that they do not induce harmful interference into other satellite orbits or the adjacent ground tracks, and thereby the resulting number of active satellites and resulting usable spectrum and transmission capacity surpasses the total quantity of effective orbital slots and transmission throughput of the current Geostationary Orbit (GSO).
14. A method as in claim 1, wherein each inclined elliptical orbit(s) has a first portion during which the satellites have a speed which is similar to the speed of rotation of the earth and a second portion during which the satellites have a speed which is not similar to the speed of the rotation of the earth.
15. A method as in claim 14, further comprising defining a measure for the satellites in the orbit, and defining phasing and spacing according to said measure.

16. A method as in claim 15, wherein said measure comprises a time when a satellite will arrive in a specified location within the orbit.
17. A method as in claim 15, wherein said phasing includes a number of standardized parameters.
18. A method as in claim 16, further comprising improvements to the satellite orbit by adding sidereal days to the specified measure.
19. A method as in claim 6, wherein a number of satellites are carefully timed or may be equidistantly phased in their orbits to optimize spacing or minimize potential interference from communication path crossovers or orbit conjunctions.
20. A method, as in claim 14, wherein a number of satellites in multiple inclined orbits are caused to share a common ground track appearing to follow each other on said ground track at preferred intervals of separation that are chosen to optimize communication link performance, resulting overall capacity in each ground track, cost and complexity of each satellite, and size/cost of receiving dishes; and where said separation may be measured in degrees of angular separation that may be in a range of angular separation of at least 4 degrees or greater, with optimal values in the 4 degree to 10 degree orbital separation range.
21. A method as in claim 15, wherein said multiple inclined orbits are each populated with 42 or more satellites per each ground track per spectrum band utilized, each spaced and controlled so that they maintain 4 degrees or more of separation from other satellites in the same repeating ground track at all times. A preferred orbital separation value may be around 9 degrees.
22. A method as in claim 1, wherein said networks may be pre-developed so that they are operational with all ancillary elements for international coordination and operation including, but not limited to, constellation fleet command and control, stationkeeping, communicating networks, regulatory approvals, licenses, preferred vendor pricing and approvals, assembly-line manufacturing, launch, and other necessary components.
23. A method as in claim 22, wherein said pre-developed satellite communication fleet, systems, or individual satellite(s) may be franchised or sub-licensed for sharing or resale by multiple users, or leased or sold to regional operators or resellers on a wholesale basis.
24. A method as in claim 22, wherein said pre-developed networks and said assembly line manufacturing may be utilized to reduce manufacturing costs; and that the

manufactured satellites may utilize a modular construction technique wherein common components are utilized on each frame or satellite bus, and frequency band-specific elements are manufactured in a modular fashion that may include a similar form and fit. Such band-specific elements may include transmitters, receivers, frequency conversion up or down converters, and antennas and associated elements.

25. A method as in claim 24, wherein said band-specific elements may utilize wideband devices. Said wideband devices may utilize solid-state devices. Said wideband devices may utilize techniques generally known as digital receiver or software-defined radio (SDR). Said SDR may assist in multi-band operation, interference reduction, modular manufacturing, or other.
26. A method as in claim 1, wherein said communication networks or arrayed constellation fleet may be caused to provide additional system bandwidth or capacity, or utilized to avoid potential interference or share spectrum with other communication links; for example by operating in multiple frequency spectrum bands planned or utilized by communication satellites, or employing additional means to reuse spectrum such as orthogonal or other polarization schemes, or employing spot-beam or other frequency or spectrum reuse techniques.
27. A method as in claim 26, wherein a satellite(s) are placed into preferred orbits and timed to arrive in the active arc transmission portion of the repeating ground track loop to coincide with peak periods of demand, and additional satellite(s) are specifically timed to be present and active during; those peak demand periods, other periods required by specific customer needs, or other market demands that may develop.
28. A method as in claim 27, wherein additional satellite capacity is timed to coincide with peak periods of demand.
29. A method as in claim 28, wherein said additional satellite capacity may be provided by utilizing higher capacity satellites, able to deliver more of said capacity during said periods of higher usage, or by other means that may deliver additional satellite capacity. Said higher capacity satellites may be formed by several methods, including; employing additional spectrum bands, utilizing larger antennas on satellites, employing more spectrum or frequency reuse, spot-beam transmissions, higher-order modulation efficiencies, on-board signal processing, artificial intelligence, or other techniques developed to cause more capacity over a satellite communications link.

30. A method as in claim 22, wherein said pre-developed satellite communication systems and links may be switched between spectrum bands or active satellites to avoid in-line path or communication link interference; or to enhance communication links, capacity or performance. Said satellite communication links may utilize L, S, C, X, Ku, Ka and Q/V bands, or any other frequency bands as licensed or approved for satellite communications by regulatory bodies.
31. A method as in claim 11, wherein satellites are operated to produce a longer active transmission portion of the repeating ground track arc, such that the active portion is about 70% of the time in each orbit; and during the active portion of the arc each satellite does not generate any appreciable or harmful electrical interference into the Clarke Belt geostationary arc.
32. A method as in claim 6, wherein satellites are placed into preferred orbits and timed to arrive in the active transmission portion of the repeating ground track arc to coincide with a location in the sky where other satellites are exiting the active transmission portion of the arc; such that switching between exiting and entering active satellites may be accomplished without re-pointing or requiring ground antennas to slew and re-point to another portion of the sky to (re)acquire an active satellite.
33. A method as in claim 1, wherein trans-continental communication from locations on the earth located within the same hemisphere (northern or southern) is enabled utilizing a single satellite transmission hop, and providing greater distance communication, lower total path delay and latency, and enabling communications at lower latitudes than allowed by other satellite communication methods.
34. A method as in claim 1, wherein broadcasting of television signals, radio, music, multimedia and one-way data transmissions are enabled over effectively most of a the hemisphere visible from a satellite(s).
35. A method as in claim 1, wherein multiple frequency spectrum bands and signal polarization schemes are available, enabled and deployed on said satellites; and said spectrum bands or polarizations are utilized to avoid possible communication interference to, or from, Low Earth Orbiting (LEO) satellites sharing or utilizing the same spectrum frequencies by switching to another transponder channel, unused frequency band, or non-interfering polarization scheme during events where the transmission paths encounter said interference as the transmission paths approach an

- intersection, conjunction or inline event, or become intersected with both satellites or their communication paths to ground stations, or generally adds interference.
36. A method as in claim 35, wherein multiple frequency spectrum bands and signal polarization schemes are available, enabled and deployed on other satellites in the array; and switching or hopping to other satellites using said spectrum bands or polarizations are utilized to avoid possible communication interference to, or from, Low Earth Orbiting (LEO) satellites sharing or utilizing the same spectrum frequencies by switching to another transponder channel, unused frequency band, or non-interfering polarization scheme during events where the transmission paths encounter said interference as the transmission paths approach an intersection, conjunction or inline event, or become intersected with both satellites or their communication paths to ground stations, or generally adds interference.
 37. A method as in claim 33, wherein live return video and telemetry & control links from UAV drones are enabled by a low-latency single hop communication link across effectively most of a hemisphere; and said single hop links may be utilized to provide real-time video from cameras mounted on or relayed from the UAVs operating in faraway regions to a controlling station, and control the UAV drone operation remotely via telemetry & command from the controlling station.
 38. A method as in claim 1, wherein broadcasting of multimedia and one-way data transmissions are transmitted to data storage devices; and said data storage devices may be located at ISP datacentres, transmission and gathering facilities, server farms, data centers, business locations, cinemas, cloud servers, points-of-presence, or other similar data receiving and storage locations.
 39. A method as in claim 1, wherein two-way voice and data communications links to wireless or cellular communication towers are enabled to provide wireless cellular service to remote and underserved regions of the world, and provide backhaul trunking connectivity to said wireless cellular towers. Said inclined elliptical orbit paths may provide higher angular separation from terrestrial services due to their higher elevation angles in many areas of the world, and may provide improved sharing and less interference than GSO orbits.
 40. A method as in claim 1, wherein two-way voice and data communications links to Wi-Fi hotspots are enabled to provide wireless internet connectivity service to remote and

underserved regions of the world, and provide backhaul trunking connectivity to said Wi-Fi hotspots and access points.

41. A method as in claim 1, wherein the satellite transmission antennas are tracked or steered such that the antennas remain centered and focused on fixed points on earth as the satellite(s) transit the said first portion of their orbits described in claim 1, and are transmitting towards the earth; and said antenna steering may be continuously performed by mechanical means, or by electronic means such as beam forming, phased arrays or other similar methods.
42. A method as in claim 1, wherein two-way voice and broadband data communication links are provided to moving vessels by steering the transmission links to areas where vessels are travelling; and said vessels may be cruise ships, commercial shipping, aircraft, UAVs, High Altitude Platforms, delivery trucks, trains, or military craft or vehicles, and said steerable transmission links may fixed or reconfigurable to form spot beams, regional beams, temporary capacity links, or other non-permanent communications to fixed points. Said inclined elliptical orbits may be preferred as they appear to be almost geosynchronous, are slow moving, have repeating ground tracks, and may have higher elevation angles.
43. A method as in claim 6, wherein secure communications by satellite is enabled by operating in the second portion of the orbit as said satellites approach and transit perigee; and said second portion of the orbit may cause said satellites to exhibit rapid movement and a high Doppler shift effect; said rapid movement and said Doppler shift may reduce the risk of interception and enhance security of the communication link, and said communication link may employ additional methods such as advanced modulation schemes that are secure, robust and jam resistant (such as spread spectrum or spiral modulation), frequency hopping across multiple bands, rapid-tracking steerable antennas, or other means.
44. A method, as in claim 1, wherein the primary communications deck of the satellite which contains the transmitting and/or receiving antennas is actively steered towards the earth beneath the satellite throughout each transit of the apogee portion of the arc to control the pitch, roll and yaw of each satellite and aid the maintenance of continuous communications with links on the ground; and said active steering may be performed by the satellite's attitude control system utilizing small thrusters or station-keeping devices, by on-board momentum or reaction wheels that provide a gyroscopic

effect to maneuver and/or stabilize the satellite positioning, by torque rods or large magnets other similar devices that utilize the earth's gravitational or magnetic fields to maintain orientation towards the earth, or by other means.

45. A method, as in claim 44, wherein a combination of the methods described are used in conjunction with each other during the same portion of the orbit arc or in different portions of the orbit arc; and where one active steering method may be preferred over the other, or to enhance, compensate, or mitigate the effects or counter-effects of the other active steering method.
46. A method, as in claim 44, wherein said methods or said combination of the methods to control said pointing or repositioning of said primary communications deck are performed during the inactive period of the satellite as it is transiting between active arcs; where the satellite pointing is not critical, or where additional power may available to be redirected to those tasks.
47. A method, as in claim 1, wherein communication to said satellites in orbit requires switching to another satellite as the first transmitting satellite exits the active portion of the orbit ground track after apogee, while a second or another satellite is operating after arriving in active portions of the ground track orbit after perigee, and in order to maintain communications from the earth the communications link will require to be switched amongst the first and second satellites; and said link switching may be switched electronically and instantaneously between the said first and second satellites by deploying electronic steering, using two communication antennas tracking each of said satellites, or by mechanical steering of an antenna and reacquiring the signal of the said second active satellite after some period of time, or other methods.
48. A method, as in claim 1, wherein independent control of said array of satellites are performed by, or within, the collective arrayed satellite fleet.
49. A method, as in claim 48 wherein said independent control of said smart devices capable of learning and independent action may be achieved by a form of artificial intelligence.
50. A method, as in claim 48, wherein said independent control is achieved by utilizing smart devices capable of learning and independent action or artificial intelligence, or other. Said independent action may be utilized to optimize communication link performance of the fleet, avoid collisions, control phasing/timing of satellite(s) in an orbit, enhancing or repairing connectivity, practising self-healing, or for other purposes.

51. A method, as in claim 1, wherein said satellites are augmented while in-orbit.
52. A method, as in claim 51, wherein said in-orbit augmentation may aid repairs, upgrades, life extension, refueling, additional capabilities, communication link performance, or other benefits.
53. A method, as in claim 52, wherein said in-orbit augmentation may be autonomously performed, and may be a 'quick-release' or 'snap-on' augmentation.
54. A method, as in claim 1, wherein a distributed database may be globally transmitted, updated, or synchronized in near real-time by said satellite system. Said distributed database may contain continuously updating records in the form of a block(s), and said block(s) may be secured by a database blockchain. Satellite-delivered blockchain data would provide networking and timestamping globally. Said blockchain distributed database could provide secure transactions and record distribution for monetary and financial transactions, medical records, identity verification, royalty payments amongst others. Said inclined elliptical orbits may be preferred over GSO for said blockchain distributed database due to wider reach, hemispheric real-time synchronization, improved latency, and better path reliability, among other benefits.
55. A method, as in claim 1, wherein said satellites are caused to decay in orbit height, or be de-orbited within a specified timeframe, as current recommendations suggest 20 years after end-of-life for de-orbiting. Said satellites may utilize drag chutes or thrusters to decay their orbit heights; said thrusters may utilize compressed gases, chemical reactions, ion propulsion, electric propulsion, or other means to lessen perigee height and increase atmospheric drag and re-entry.
56. A method, as in claim 1, wherein said communications networks may utilize earth stations on the ground to communicate with the satellite networks. Said earth stations may be gateway hubs or remote sites, and said earth stations may require steerable antennas to improve communication link performance. Said steerable antennas may be mechanically or electronically steered. Said steering may also enable switching to alternate satellites as they cease transmissions and exit their active arc portion of the orbit.
57. A method, as in claim 56, wherein a preferred embodiment is multi-band steerable antennas. Said multi-band steerable antennas may be caused to operate over several octaves of frequency to be capable of utilizing all planned satellite communications bands (approximately 4-50 GHz). Said multi-band steerable antennas may comprise a

type of digital air interface (DAI) capable of working across several octaves of frequency range. Said DAI may also have improved efficiency generally higher than 60%; preferably more than 90% efficiency.

58. A method, as in claim 56, wherein said multi-octave DAIs in combination with SDR-capable satellites may enable operation over several frequency bands, band-hopping, and beam switching capabilities on said satellite communication networks similar to wireless mobile phone networks.
59. A method, as in claim 1, wherein said satellites are insulated or protected with radiation shielding or dissipating features to limit effects of Van Allen Belt radiation and electrostatic discharge effects in space.
60. A method, as in claim 59, wherein said shielding may generally comprise metal or plastic shielding, or more generally lightweight shielding materials having protective properties against ionizing radiation; said lightweight shielding materials may include aluminum, polypropylene, boron carbide or other materials, or utilize combinations of said lightweight shielding materials, e.g., an aluminum sheet over a polypropylene layer which said aluminum sheet may have desired effects of electrical conductance or electrostatic dissipation in addition to shielding.

FIG. 1

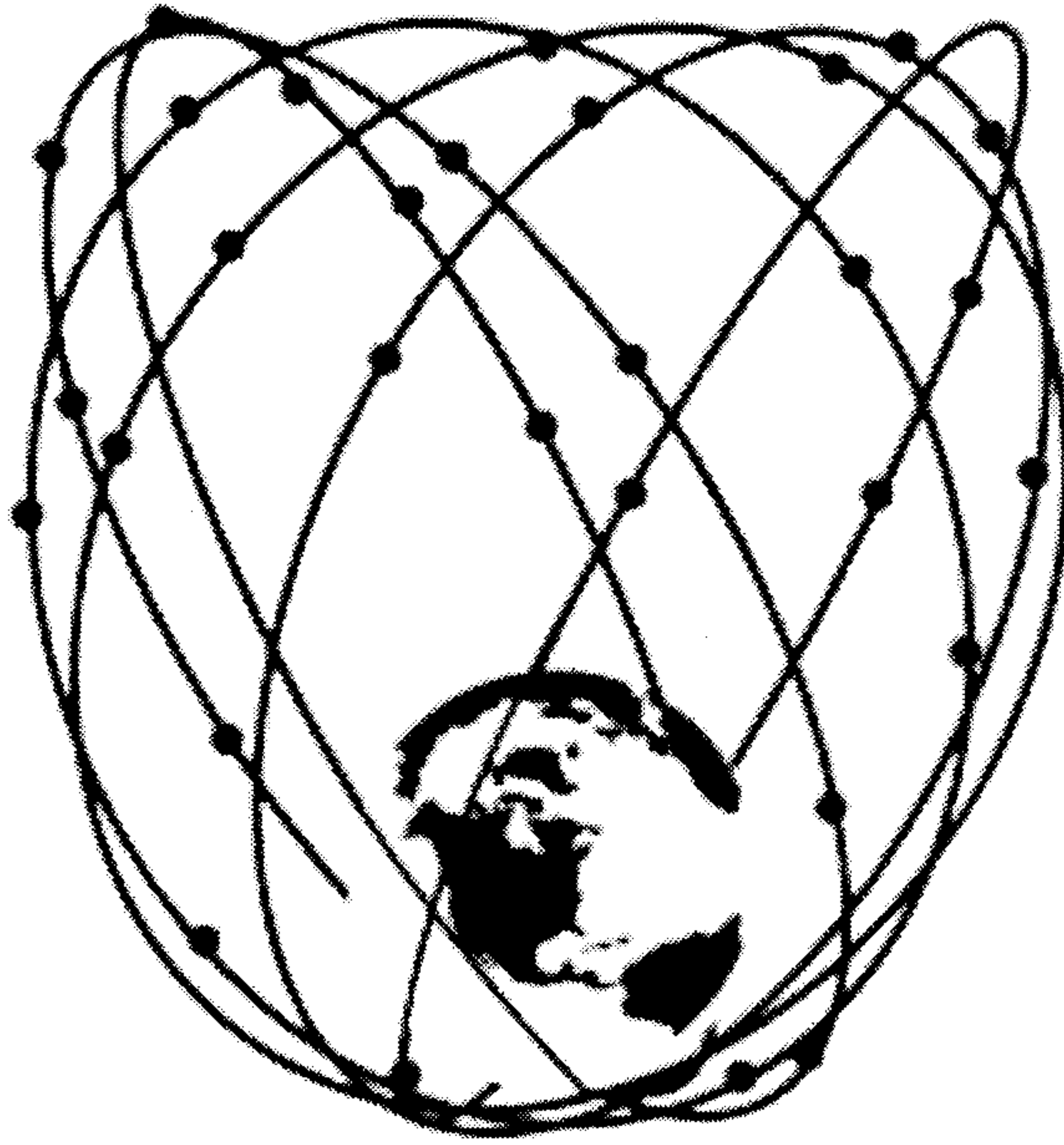


FIG. 2

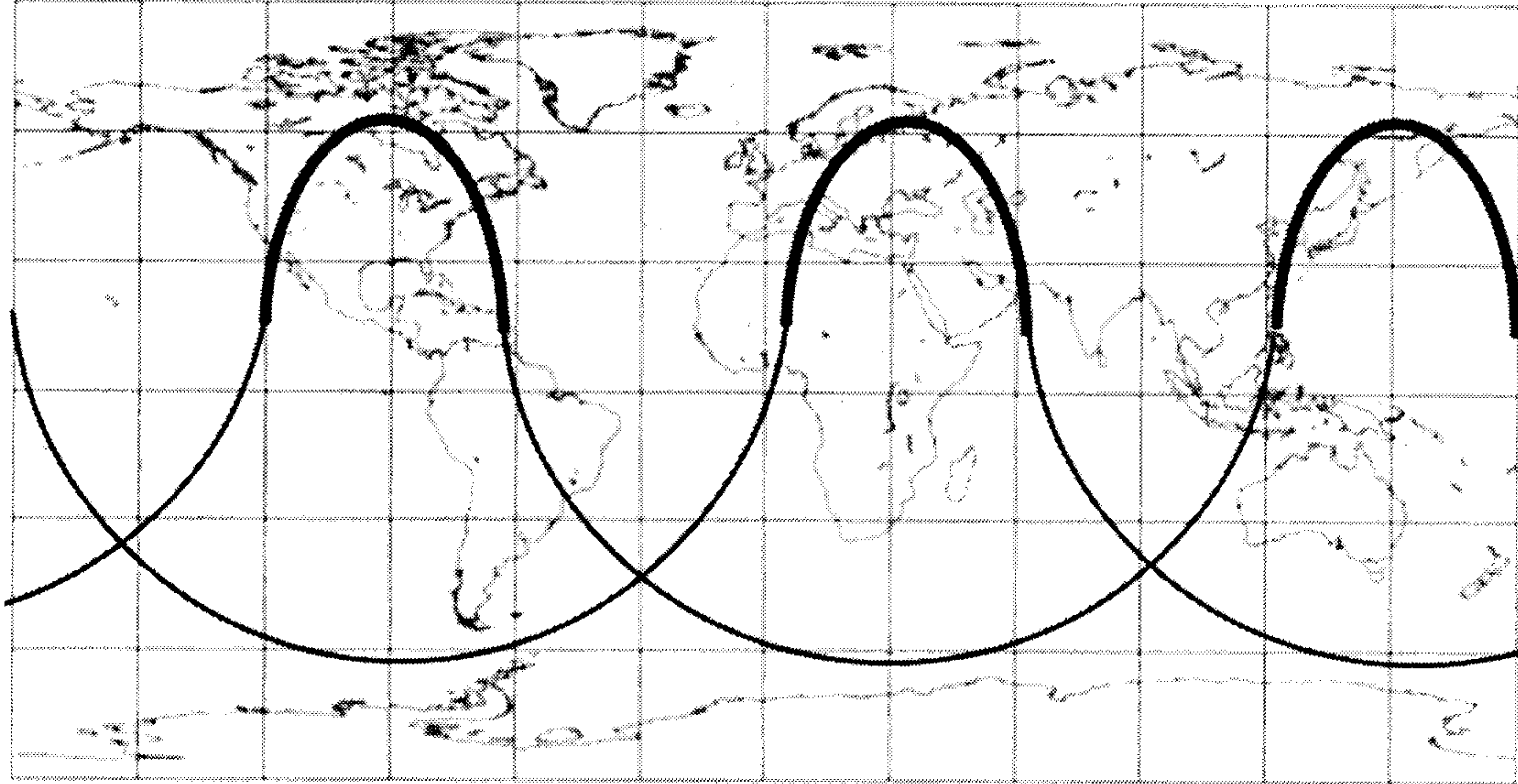


FIG. 3

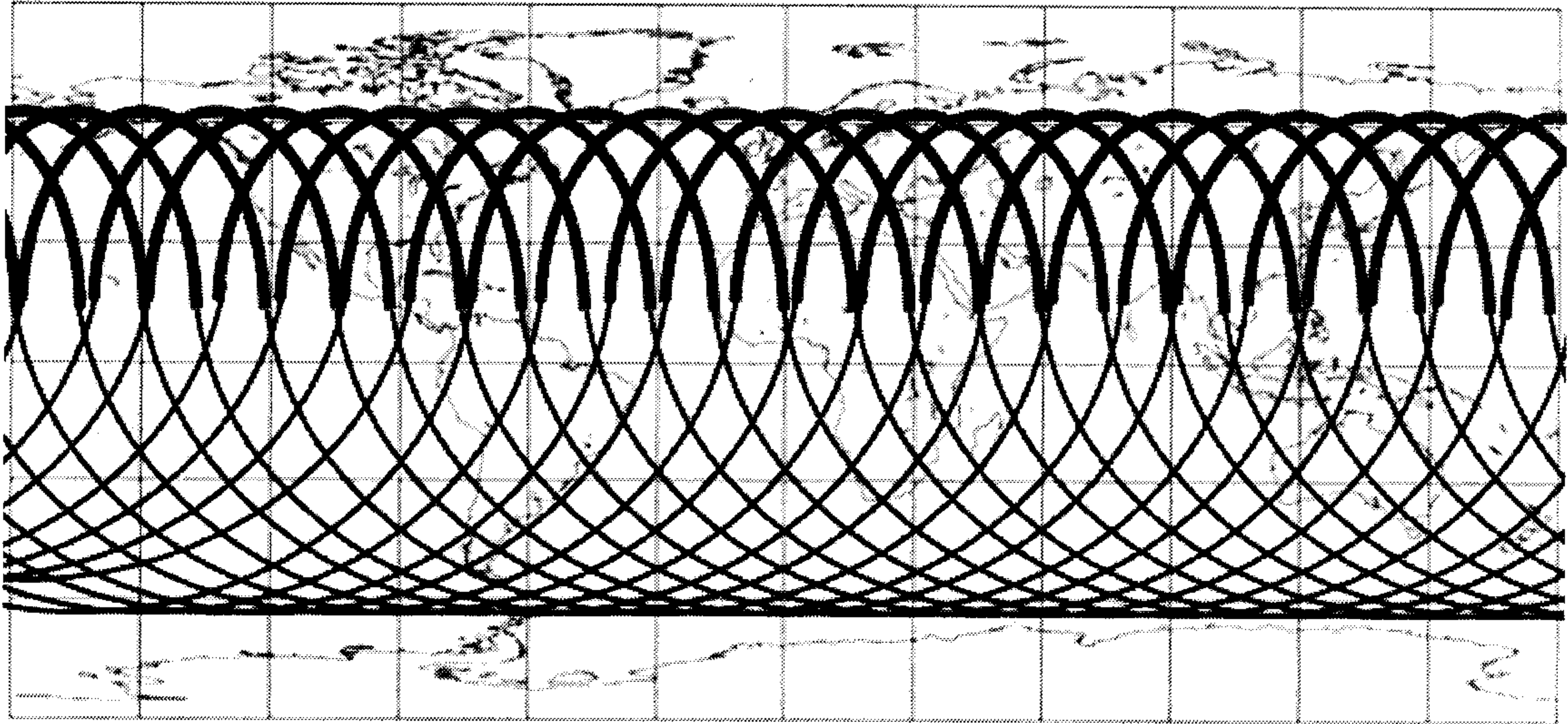


FIG. 4

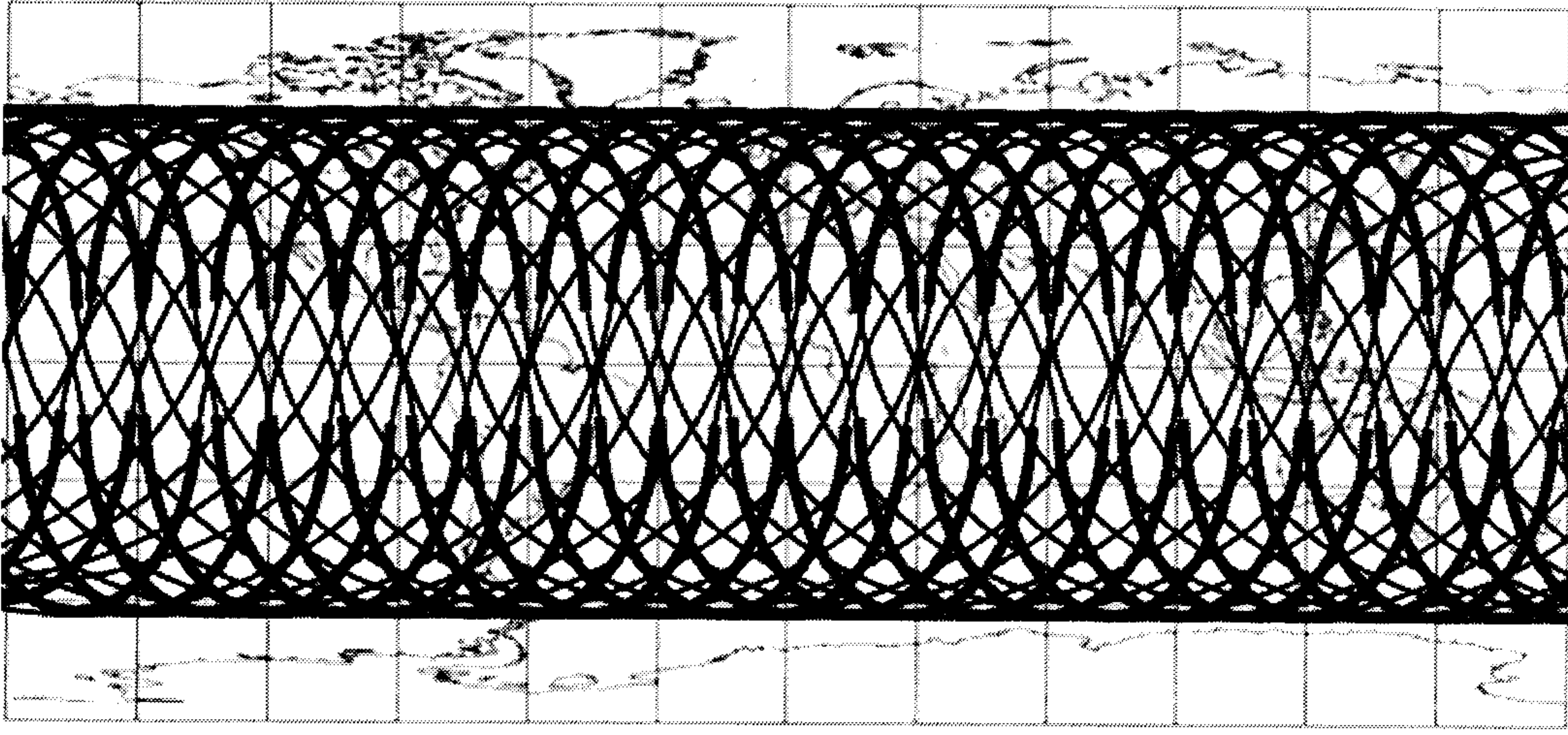


FIG. 5

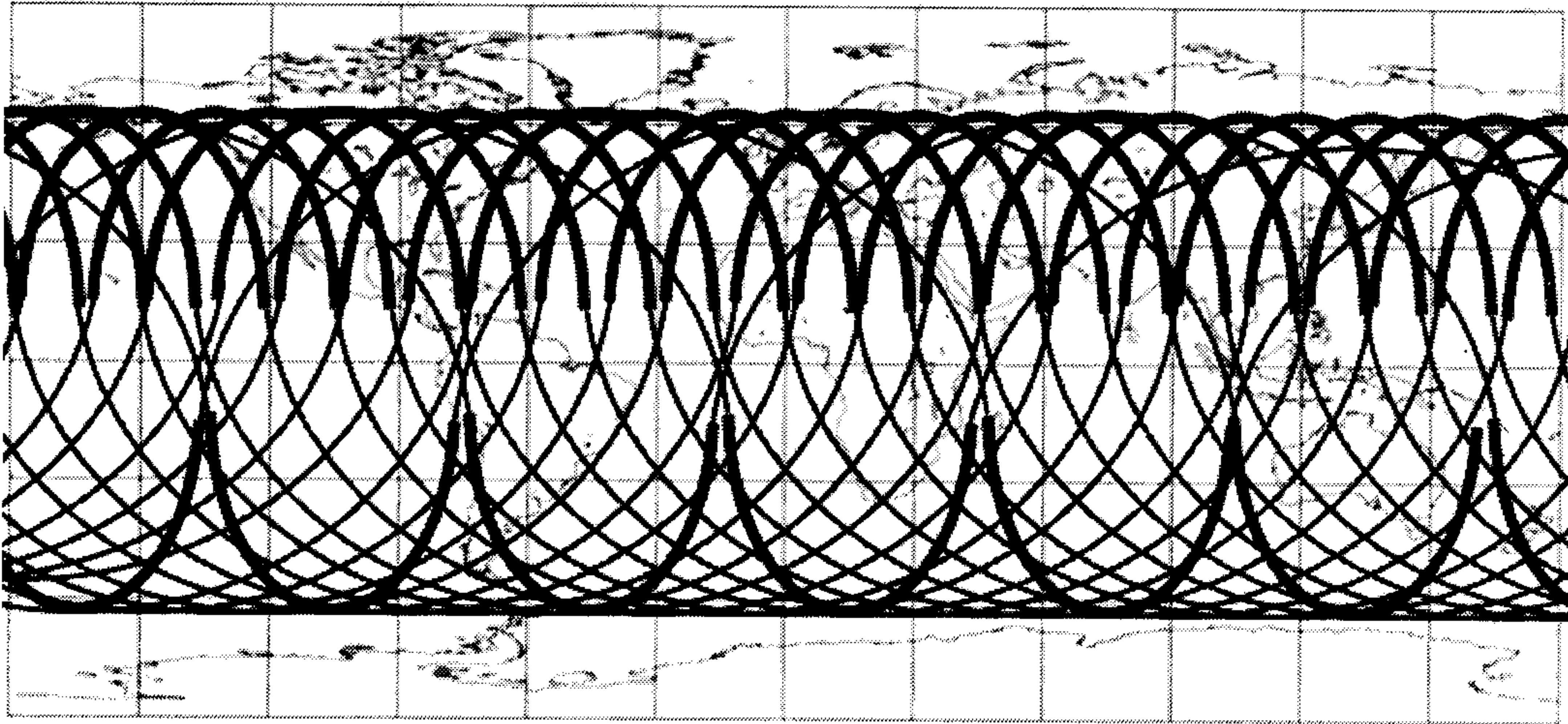


FIG. 6

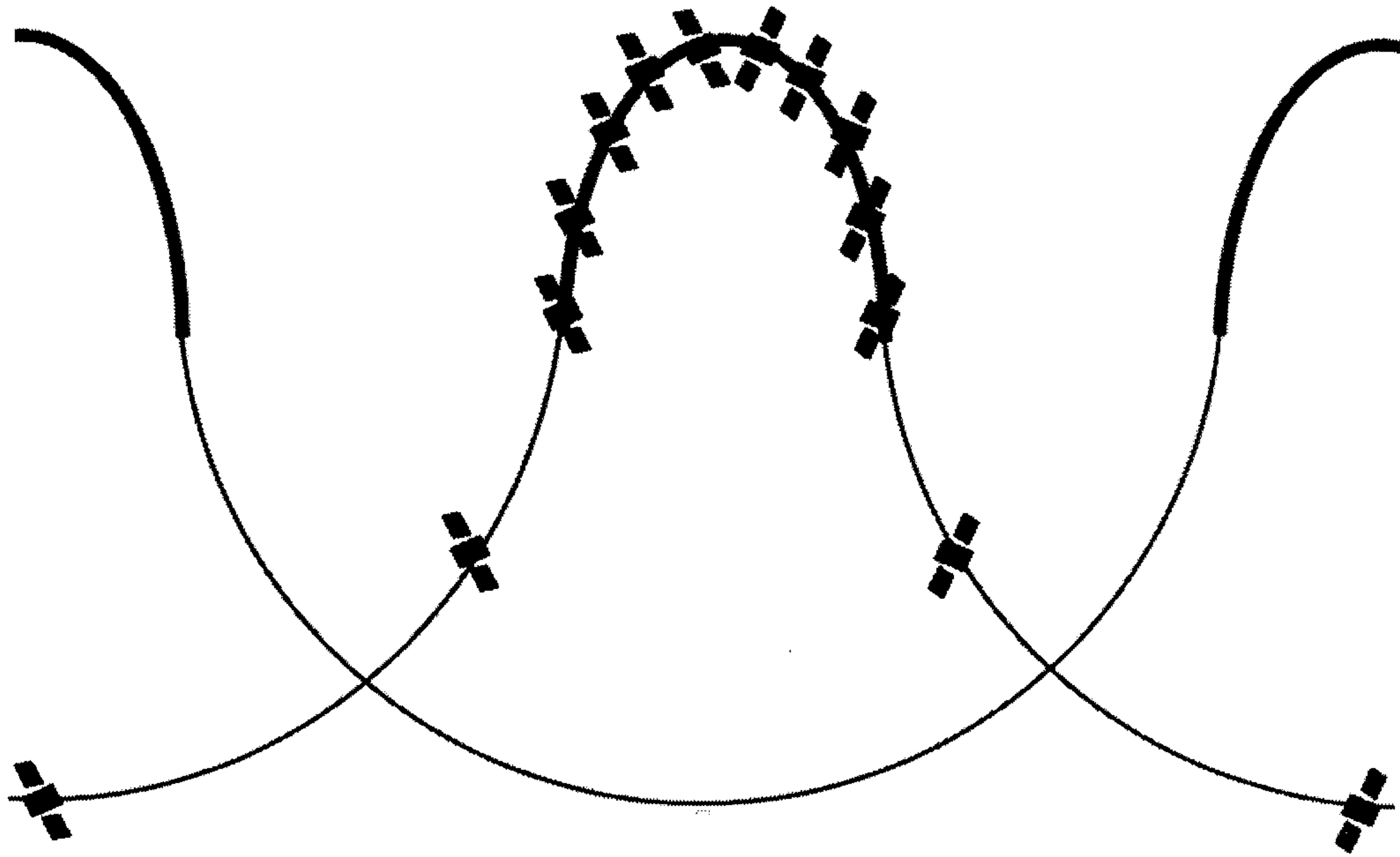


FIG. 7

