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Federal Communications Commission
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SAT-LOA-19990108-00007

Re: **Application of Virtual Geosatellite, LLC for Authority to Launch and Operate a Global System of Non-Geostationary Satellites in Sub-Geosynchronous Elliptical Orbits**

To Whom It May Concern:

On behalf of Virtual Geosatellite, LLC ("Virtual Geo"), and pursuant to Section 25.110 of the Commission's Rules, enclosed are the original and nine (9) copies of Virtual Geo's application for authority to launch and operate a global fixed-satellite service system of technically-identical non-geostationary satellites in sub-geosynchronous elliptical orbits. Virtual Geo's proposed satellite system will employ fifteen non-geostationary spacecraft in three orbital sub-constellations, and will utilize spectrum in the Ku-band and C-band frequency ranges for its user and gateway links. The system also includes three in-orbit spare spacecraft.

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Should there be any questions concerning this application, please contact the undersigned.

Respectfully submitted,

Stephen D. Baruch
Counsel for Virtual Geosatellite, LLC

SDB/yeg
Enclosure

cc (by hand): Chairman Kennard
Commissioner Ness
Commissioner Furchtgoth-Roth
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BEFORE THE

FEDERAL COMMUNICATIONS COMMISSION

Washington D.C. 20554

APPLICATION OF

VIRTUAL GEOSATELLITE, L.L.C.

FOR AUTHORITY TO LAUNCH AND OPERATE

virgo

A GLOBAL FIXED-SATELLITE SERVICE SYSTEM EMPLOYING NONGEOSTATIONARY SATELLITES IN SUB-GEOSYNCHRONOUS ELLIPTICAL ORBITS

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Executive Summary

Virtual Geosatellite, LLC ("Virtual Geo") hereby seeks authority to launch and operate a state-of-the-art system of fifteen (15) non-geostationary satellites in sub-geosynchronous inclined elliptical orbits. Virtual Geo's proposed system, called "VIRGO™," will provide fixed-satellite services to all of the world's populated land masses through a combination of user and gateway links in the C-band and Ku-bands, as well as through inter-satellite links in the optical frequencies.

VIRGO™ is the first of a new class of constellation systems that are virtually geo-synchronous. Unlike geostationary systems or so-called "quasi-geostationary" systems in which the individual satellites attempt to follow the Earth, all of the satellites in a virtual geostationary system, as a whole, follow the Earth in a dynamically geosychronous manner. It is this feature which gives this constellation type the name "virtual geo."

Using a continent-following orbital configuration that is covered by issued and pending patents, the VIRGO™ constellation, though operating at non-geostationary altitudes, will appear virtually geostationary to users within the system's coverage area. VIRGO™ is comprised of three five-satellite sub-constellations – two for Northern Hemisphere operation (and identified herein as "Aurora I™" and "Aurora II™") and one for Southern Hemisphere operation (identified herein as "Australis™"). The active arcs of the VIRGO™ satellites in each sub-constellation occur only when the satellites are at latitudes above 45 degrees, when they are at high elevations over much of their primary service areas in the Northern and Southern Hemispheres, respectively. VIRGO™ thus achieves an optimized combination of very high elevation angles, low signal propagation delays compared to geostationary satellites, and limited

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VIRGO™ is the first of a new class of constellation systems that are virtually geo-synchronous. Unlike geostationary systems or so-called "quasi-geostationary" systems in which the individual satellites attempt to follow the Earth, all of the satellites in a virtual geostationary system, as a whole, follow the Earth in a dynamically geosychronous manner. It is this feature which gives this constellation type the name "virtual geo."

Using a continent-following orbital configuration that is covered by issued and pending patents, the VIRGO™ constellation, though operating at non-geostationary altitudes, will appear virtually geostationary to users within the system's coverage area. VIRGO™ is comprised of three five-satellite sub-constellations – two for Northern Hemisphere operation (and identified herein as "Aurora I™" and "Aurora II™") and one for Southern Hemisphere operation (identified herein as "Australis™"). The active arcs of the VIRGO™ satellites in each sub-constellation occur only when the satellites are at latitudes above 45 degrees, when they are at high elevations over much of their primary service areas in the Northern and Southern Hemispheres, respectively. VIRGO™ thus achieves an optimized combination of very high elevation angles, low signal propagation delays compared to geostationary satellites, and limited satellite handoffs. VIRGO™ provides non-uniform distribution of capacity to the Northern and Southern Hemispheres in proportion with demand.

Morevoer, VIRGO™ operates in a manner that is effectively transparent to the geostationary fixed-satellite service ("FSS") and geostationary broadcasting satellite service ("BSS") networks, and to the fixed service systems, with which it will operate on a co-primary and fully compatible basis. Although sharing between VIRGO™ and other types of non-geostationary systems is more complex than sharing with either geostationary networks or fixed service systems, Virtual Geo believes that with proper coordination and a multilateral commitment to interference mitigation, a significant level of co-frequency operation among inhomogeneous nongeostationary FSS systems should be attainable.

VIRGO™ satellites are separated from the geostationary arc by at least 40 degrees at all times within the system's service areas. This key feature of the virtual geostationary concept means that VIRGO™ not only fully protects current geostationary FSS and BSS networks, it leaves them an effectively unfettered opportunity to evolve their technologies to meet future service requirements.

At a minimum, VIRGO™ will provide continuous coverage of all points on the globe between 85° north latitude and 55° south latitude. This includes all of the world's populated land masses. Emphasis is placed on key Northern Hemisphere locations such as the continental United States, Alaska, Hawaii, the U.S. Virgin Islands, and Puerto Rico.

VIRGO™ will operate with user links in the 14.0-14.5 GHz band (Earth-to-space) and in the 11.2-12.7 GHz band (space-to-Earth), and with gateway links in the 12.75-13.25 GHz, 13.8-14.0 GHz, 17.3-17.8 GHz, and 5.925-6.725 GHz bands (Earth-to-space) and the 10.7-11.2 GHz and 3.7-4.2 GHz bands (space-to-Earth). Each VIRGO™ satellite provides "bent pipe"

systems to be implemented on a co-frequency basis – without disturbing the sharing situation with geostationary satellites or terrestrial systems.

In short, with VIRGO™, Virtual Geo offers the world a novel, efficient, and affordable satellite system that is technically benign with respect to other types of users of the spectrum within which the system will operate. Virtual Geo is legally and technically qualified to be a Commission licensee. Although Virtual Geo believes that the strict financial qualification standard the Commission has proposed for this service is inappropriate, Virtual Geo will meet whatever financial qualification standard, if any, the Commission sees fit to impose on nongeostationary FSS systems at Ku-band. Virtual Geo thus urges the Commission to conclude that the grant of its application to launch and operate VIRGO™ will advance the public interest, convenience, and necessity.

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In re the Application of VIRTUAL GEOSATELLITE, LLC For Authority to Launch and Operate a Global Fixed-Satellite Service System Employing Nongeostationary Satellites in Sub-Geosynchronous Elliptical Orbits in Ku-Band and C-Band Frequencies	)))))))))	File No. ________

APPLICATION OF VIRTUAL GEOSATELLITE, LLC

Virtual Geosatellite, LLC ("Virtual Geo"), pursuant to Sections 308 and 309 of the Communications Act of 1934, as amended, 47 U.S.C. §§ 308 and 309 (1996), Parts 1 and 25 of the Commission's Rules, and the Commission's Public Notice (Report No. SPB-141, released November 2, 1998), hereby seeks authority to launch and operate a state-of-the-art system of fifteen (15) non-geostationary satellites in sub-geosynchronous inclined elliptical orbits. Virtual Geo's proposed system, called "VIRGO™," will also include three additional in-orbit spare satellites that will be placed into a parking orbit. VIRGO™ will provide fixed-satellite services to all of the world's populated land masses through a combination of user and gateway links in the C-band and Ku-bands, as well as through inter-satellite links in the optical frequencies.

VIRGO™ is the first of a new class of constellation systems that are virtually geo-synchronous. Unlike geostationary systems or so-called "quasi-geostationary" systems in which the individual satellites attempt to follow the Earth, all of the satellites in a virtual geostationary system, as a whole, follow the Earth in a dynamically geosychronous manner. It is this feature which gives this constellation type the name "virtual geo."

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VIRGO™ satellites are separated from the geostationary arc by at least 40 degrees at all times within the system's service areas. This key feature of the virtual geostationary concept means that VIRGO™ not only fully protects current geostationary FSS and BSS networks, it leaves them an effectively unfettered opportunity to evolve their technologies to meet future service requirements.

1 Introduction

This application and its appendices contain all of the information required for a space station authorization as specified in Part 25 of the Commission's Rules. In accordance with the Commission's recent *Public Notice* concerning the streamlining of the application process,[1] the information provided throughout this application includes references to the specific subsections of Section 25.114(c) of the Commission's Rules to which the submitted information pertains. To the greatest extent possible, these items appear in numerical order. FCC Form 312 (February 1998 version) is attached hereto as Appendix A.

Consistent with Commission policy and precedent, and with the above-referenced Public Notice, Virtual Geo understands that it will be afforded an opportunity to amend or supplement this application, if necessary, "to conform to any requirements and policies that may be adopted subsequently for space stations concerning the provision of NGSO fixed-satellite service in [the Ku] frequency bands." Public Notice, Report No. SPB-141, at 3. Virtual Geo specifically requests such an opportunity to conform its VIRGO™ system proposal to the rules that may ultimately be adopted in the ongoing rulemaking proceeding in ET Docket No. 98-206.[2] It also requests that a similar opportunity be provided with respect to its proposed use of C-band frequencies.

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1 *See FCC Public Notice*, "International Bureau to Streamline Satellite and Earth Station Processing," Report No. SPB-140 (released October 28, 1998).

2 *See Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range and Amendment of the Commission's Rules to Authorize Subsidiary Terrestrial Use of the 12.2-12.7 GHz Band by Direct Broadcast Satellite Licensees and Their Affiliates*, ET Docket No. 98-206, FCC 98-310 (released November 24, 1998) (Notice of Proposed Rule Making) ("*Ku-Band NRPM*").

1.1 Name and Address of Applicant (47 C.F.R. § 25.114(c)(1))

The applicant for the authority to launch and operate the proposed satellite system is:

Virtual Geosatellite, LLC
1133 21st Street, N.W.
8th Floor
Washington, DC 20036
(202) 466-5599

1.2 Correspondence (47 C.F.R. § 25.114(c)(2))

Correspondence and communications concerning this application should be addressed to the following:

Dr. David Castiel
Managing Director
Virtual Geosatellite, LLC
1133 21st Street, N.W.
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1.3 Type of Authorization Requested (47 C.F.R. § 25.114(c)(3))

In this Application, Virtual Geo requests authority to launch and a license to operate a constellation of nongeostationary satellites.

1.4 Overview of Virtual Geo and the "VIRtual Geostationary Orbit" Concept

Virtual Geo, a Delaware limited liability company, was founded by David Castiel, founding principal of Mobile Communications Holdings, Inc. ("MCHI"), licensee of the Ellipso™ mobile-satellite service ("MSS") system in the "Big LEO" MSS bands at 1610-1626.5

MHz and 2483.5-2400 MHz. Virtual Geo's majority owner holds intellectual property rights (consisting of U.S. and foreign patents and patent filings) relating to the use of constellations of elliptical orbit satellites in the field of communications and data transfer. These patents cover the arrangement and phasing of the satellites in the constellation, and cover as well the strategy for power management in the unique elliptic orbits selected.

Virtual Geo's innovation in orbital configuration confers two major benefits. First, the earth terminals associated with Virtual Geo's system point at an entirely different portion of the sky from that occupied by geostationary satellites with which it will operate on a co-frequency basis. This means that there will be no radio frequency interference with the heavily-used geostationary arc. Second, due to the reduced velocity of the elliptical satellites at and near apogee, the active satellites appear to "hang" in the sky, as their rotational velocity more nearly matches that of the earth than is the case with nongeostationary satellites in circular orbits. In addition, the use of elliptical orbits with periods of less than 24 hours permits the use of smaller satellites and smaller launch vehicles, and thus contributes to the provision of a more cost-effective service.

The concept behind the "virtual geostationary" orbit can be illustrated with a simple analogy – the walking juggler. A juggler's clubs cluster together and move very slowly at the highest point in their trajectories; conversely, at the low point in the trajectories, the juggler is catching and transferring the clubs from hand-to-hand in rapid sequence, propelling each one in turn into its new upward trajectory. In a similar fashion, the satellites in a virtual geostationary constellation, which are intentionally placed in stable elliptical orbits with the apogees over intended users, will rise over the service area and appear to hang there (as the orbital velocity at and near apogee is relatively low, and can approach the velocity of a true geostationary satellite).

Using a Northern Hemisphere apogee orbit as an example, as the satellite is replaced after its hang time by the next satellite in the array, it falls rapidly into the Southern Hemisphere, quickly rising in the next adjacent Northern Hemisphere peak where it will repeat the process.

In the case of VIRGO™, the critical inclination of the elliptical planes in the two Northern Hemisphere sub-constellations is 63.4° with respect to the plane of the equator, meaning that the apogees will always appear to be roughly at 63.4° North Latitude.[3] Through the use of overlying, repeating ground tracks, the satellites, which have roughly 8 hour orbits, will have three peaks each day, each peak being separated by exactly 120° in longitude. By strategically placing the peaks, Virtual Geo is able to place each satellite's peak over one of the three Northern Hemisphere continental masses – North/Central America, Asia, and Europe/Northern Africa – once each day.

The active arc of the VIRGO™ satellites is limited to orbit locations displaced in latitude greater than 40 degrees from the equator and operating at altitudes exceeding 17,500 kilometers. Earth terminals associated with VIRGO™ will be pointed well away from the equator to the North or South, depending on the hemisphere in which the user terminal is located. In other words, VIRGO™ users and geostationary FSS and BSS users are looking at different regions of the sky at all times. Thus, there is no opportunity for in-line interference events between the virtual geostationary VIRGO™ system and the geostationary FSS and BSS networks. It is as if the geostationary arc, for all of its congestion, did not exist, and the virtual geostationary orbit fixed-satellite service was to be established in fallow spectrum.

---

3 Two five-satellite sub-constellations, Aurora I™ and Aurora II™, are used to achieve continuous Northern Hemisphere coverage (between 85° North Latitude and 10° South Latitude). The phasing of the sub-constellations enables Virtual Geo to concentrate coverage on the populated land masses in the northern latitudes.

The key to the Virtual Geo's innovative virtual geostationary orbit concept is its transparency to co-frequency users of the geostationary orbit. Virtual Geo has combined this revolutionary approach with an orbital configuration that is optimized to maximize coverage of the continental land masses at altitudes substantially lower than geosynchronous -- and created a business.

2 Types of Services to be Provided

VIRGO™ will provide state-of-the-art, affordable, digital fixed-satellite services directly to users throughout its global service area. *See* Section 3.3, below. VIRGO™ will be capable of accommodating very small earth terminals (on the order of 45 centimeters or 18 inches in diameter). VIRGO™'s gateway terminals will be larger, but may also be located on the premises of service providers or at the headquarters of corporate customers.

Among the many service offerings attainable through VIRGO™ are high-speed Internet access at megabit rates, video and broadband data distribution, and two-way video conferencing.

3 System Description (47 C.F.R. §§ 25.114 (c)(4) – (c) (12))

3.1 System Overview

3.1.1 Overall System Concept

The VIRGO™ global satellite communications system has been designed to meet the needs of its users. These are:

- Provision of state-of-the-art digital two-way telecommunications services;
- Very high service availability, even at high northerly and southerly latitudes, due to the near ideal elevation angles from the user terminals to the VIRGO™ satellites;
- Lower signal delay compared to geostationary satellite systems;
- Low-cost user terminals;
- Low-cost service.

The VIRGO™ system achieves these goals primarily as a result of its novel orbit constellation. The VIRGO™ satellites will operate in inclined elliptical orbits such that their active arcs occur when the satellites are at high latitudes and elevations over the primary service areas in the Northern and Southern hemispheres. These patented and patent pending orbits have been carefully selected to optimize the range of elevation angles to the users, the required service areas, the angular separation from the GSO orbit, the round-trip signal delay, and the total cost of the satellite constellation.

The VIRGO™ system will provide state-of-the-art digital services directly to small user terminals located on the premises of residential and small business users. The high satellite downlink EIRP and uplink sensitivity allows for small (45 cm/18 inch) user terminals. These user terminals will be connected through the VIRGO™ satellites to gateway earth stations which may be located on the premises of service providers or at the headquarters of corporate customers. The VIRGO™ system is very spectrally efficient, with a frequency re-use factor of fourteen times in the majority of its user terminal frequency bands.

Key to the VIRGO™ system's success is the use of conventional Ku and C frequency bands, where the ground and space segment components are readily available at low cost as a result of the massive existing usage of these frequency bands by geostationary ("GSO") satellite systems throughout the world. The VIRGO™ system, however, stands apart from all other non-geostationary ("NGSO") systems proposed to date for operation in these GSO frequency bands; it represents no threat of unacceptable interference – in the present or foreseeable future - to co-frequency GSO systems, because it only operates when its satellites are at least 40 degrees away from the line-of-sight to and from GSO satellites. As a result it represents a perfect "band-sharing" partner for GSO systems.

3.1.2 Space Segment

The VIRGO™ orbits are designed to position individual satellites for the maximum period of time at the highest elevation over the primary service areas, while at the same time maximizing the angular separation from the GSO orbit. These parts of the orbit where the VIRGO™ satellites are active are close to the orbit apogee. As each VIRGO™ satellite moves away from its near-apogee position another VIRGO™ satellite rises to a near-apogee position. The VIRGO™ user and gateway terminals switch as necessary between the VIRGO™ satellites that are close to apogee in order to provide continuous 24 hour per day uninterrupted service to the users.

The details of the VIRGO™ orbit constellation are provided later in Section 3.2. For the purpose of this section, it is sufficient to summarize the features of the VIRGO™ constellation as follows:

- Fifteen active satellites in fifteen orbit planes, one per plane, plus three spare satellites in "parking" orbits;
- Active part of the VIRGO™ orbit occurs between altitudes of 17,500 km and 27,300 km above the surface of the Earth, at sub-satellite latitudes that are always above 45 degrees.

Each VIRGO™ satellite provides "bent-pipe" communications channels in the Ku and C band frequency ranges detailed in Section 3.4 below. VIRGO™ achieves a frequency re-use factor of fourteen times for the user terminal frequency bands and eight times for the gateway terminal frequency bands per satellite, and respectively 126- and 72-times frequency reuse system-wide. This is obtained by the use of dual orthogonal circular polarizations, and through the use of spatial separation of the individual uplink and downlink beams. The multi-beam coverage is implemented using active phased array antennas on the satellites, thereby allowing the VIRGO™ satellites to optimally reconfigure their coverage for the service area corresponding to each apogee and for the particular traffic requirements as the satellite moves and as demand varies. In addition, the use of an active phased array satellite antenna allows the beam configuration on the Earth's surface to be made nearly constant as the satellite passes through its apogee, despite the 34% variation in altitude between the peak of the apogee and the points in the orbit where each satellite starts and ends its active service arc.

Finally, VIRGO™ will also include on-board storage capability for time and geographically shifted digital service retransmissions.

3.1.3 Ground Segment

The VIRGO™ ground segment is made up of the following types of terminals and facilities:

User Terminals: There will be vast numbers of these small and low-cost terminals deployed on the premises of residential and business users. They will provide a wide range of two-way (as well as one-way) digital communications services. The user terminals have the capability to track the active VIRGO™ satellite and seamlessly switch between active satellites when necessary. In addition, the terminals will be designed to acquire and maintain tracking reliably, and will employ uplink power control to maximize system performance and minimize interference to other users of the spectrum.

The user terminals are described in more detail in Section 3.16.1 below.

Gateway Terminals: There will be four gateway terminals in each regional service area of the VIRGO™ system, each equipped with two large tracking antennas. These gateway terminals will act as the "hub" facilities for the user terminal links, and will connect the user terminals to the terrestrial communications infrastructure within the respective service areas. In addition any required links between two or more user terminals will connect through a gateway terminal. The gateway terminals also generate and transmit control information destined for the user terminals to assist in user terminal tracking and in the application of uplink power control by the user terminals. The gateway terminals are connected by terrestrial links to the Regional Network Control Center ("RNCC") and the primary Spacecraft Operations Control Center ("SOCC").

The gateway terminals are described in more detail in Section 3.16.2 below.

Regional Network Control Centers ("RNCC"): There will be three Regional Network Control Centers ("RNCCs"). Each RNCC manages the entire satellite resources available to the region by assigning capacity to user terminals upon request, and collecting system usage data for billing purposes.

The RNCCs are described in more detail in Section 3.16.3 below.

Spacecraft Operations Control Center ("SOCC") and TT&C Earth Stations: There will be a single primary Spacecraft Operations Control Center ("SOCC") in the VIRGO™ system plus a back-up facility. The SOCC will be connected by land-lines to regional TT&C earth stations located in the regional service areas. The SOCC will perform all spacecraft control and monitoring functions for the entire VIRGO™ constellation.

The SOCC and associated TT&C earth stations are described in more detail in Section 3.16.4 below.

3.2 VIRGO™ CONSTELLATION

The VIRGO™ Constellation uses a carefully synchronized array of fifteen satellites in individual elliptical orbits to form three ground tracks of five satellites each.[4] The orbits are constructed to place satellite operating arcs ("active arcs") over important market areas in the Northern and Southern hemispheres. These active arcs are well displaced to the north and south of the GSO arc. Orbital parameters have been further selected for good constellation efficiency and desirable path characteristics.

4 Note that VIRGO™ orbits are arranged to form common ground tracks with unique orbits, whereas conventional constellations of satellites (such as Walker Constellations) are arranged to form common orbits using unique ground tracks.

Each satellite flies in a highly elliptical orbit whose apogee is placed either at the northernmost or southernmost extent of satellite travel. Satellites require an eight hour orbital period to complete one revolution, of which 4 hours and 48 minutes are spent on an active arc whose sub-satellite point is 45 degrees or more in latitude from the equator. After departing one active arc, each satellite passes quickly toward and through perigee in the opposite hemisphere to return to its next active arc on its ground track (being the next one to the west). Table 3.2-1 presents the orbital parameters of the 15 active satellites and three spares in the VIRGO™ System. Figure 3.2-1 illustrates the ground tracks, highlighting the active arcs.

Table 3.2-1: VIRGO™ Orbital Characteristics

	Aurora I™ Sats n=1-5	Aurora II™ Sats n=1-5	Australis™ Sats n=1-5	Spare Satellites
Semimajor Axis	20281	20281	20281	7285
Eccentricity	0.66	0.66	0.66	0.05346
Inclination	63.435	63.435	63.435	63.435
Right Ascension of the Ascending Node	341.5 53.5 125.5 197.5 269.5	255.3 327.3 39.3 111.3 183.3	52.2 124.5 196.5 268.5 340.5	0 180 30
Argument of Perigee	270 270 270 270 270	270 270 270 270 270	90 90 90 90 90	270 270 90
Mean Anomaly	0 144 288 72 216	108.2 252.2 36.2 182.2 324.2	0 144 288 72 216	0 0 0

The apogee of VIRGO™ satellites, at 27,300 kilometers, is around three-quarters of the altitude of geostationary satellites. This lower apogee results in less propagation delay than encountered with GSO satellite service or when using satellites in Molnya or higher orbits, and yields excellent coverage of northern and southern service areas. The VIRGO™ System offers pole-to-pole Earth coverage of all populated landmass areas. It is optimized to offer its highest elevation angles over primary markets around the world, while devoting less coverage resource to ocean areas.

The angular separation between VIRGO™ satellites in the active VIRGO™ arc and the GSO orbit always exceeds 45 degrees regardless of location on the Earth. This ensures at least 40 degrees of separation from GSO satellites operating in up to 5 degree inclined orbits. The lowest angular separation occurs for stations to the far north or far south, such as for those in Alaska. Stations within the continental United States operate with angular separations to the GSO arc exceeding 50 degrees. The VIRGO™ system will apply design and operating limits to ensure that no VIRGO™ link operates with less than 40 degrees of separation from the GSO arc, even in anomalous circumstances (a margin of 5 degrees). As a consequence, as described in further detail in Section 3.13.1, VIRGO™ satellites and ground stations generate significantly less interference toward geostationary systems than the provisional limits already under consideration by the international satellite community.

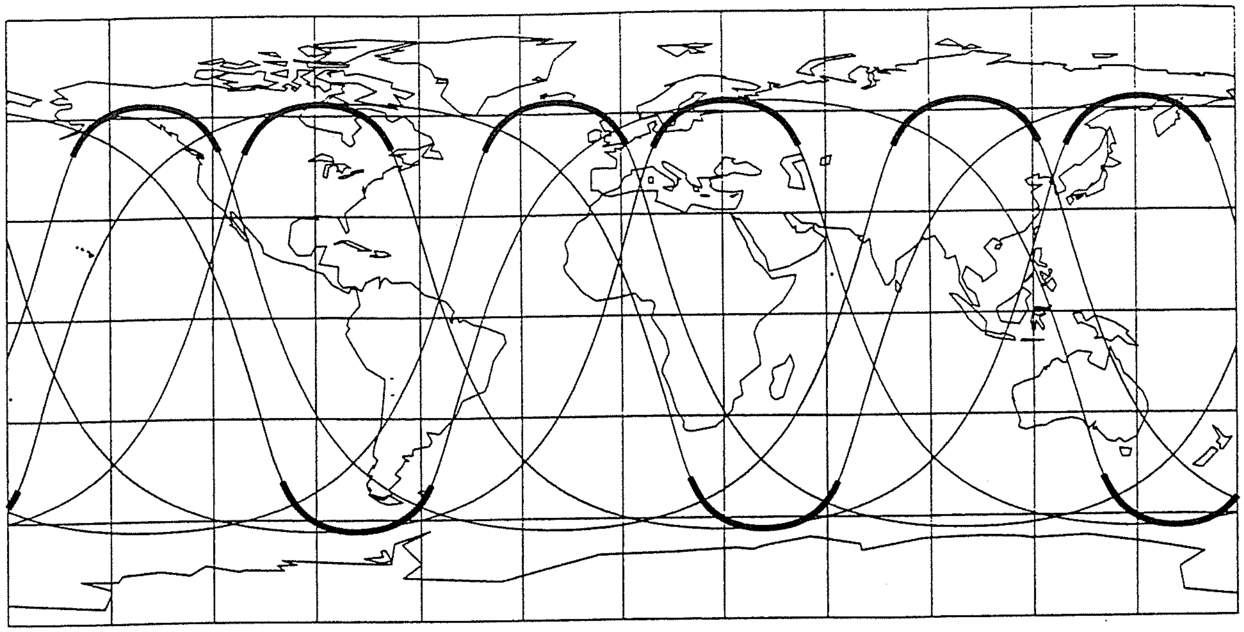


Figure 3.2-1: VIRGO™ Satellite Ground Tracks

VIRGO™ creates six active arcs over the northern hemisphere and three over the southern. Each active arc covers 45 degrees of longitude in the positions noted in Table 3.2-2. More active arcs are deployed in the northern hemisphere than in the southern hemisphere due to the greater land area in the northern hemisphere than in the southern. The Northern (Aurora™) and Southern (Australis™) service areas join without gap in the equatorial region, completing global coverage.

Table 3.2-2: **Locations of the VIRGO™ Active Arcs (Sub-satellite Longitudes in ° East)**

Aurora I™ Northern Hemisphere	Aurora II™ Northern Hemisphere	Australis™ Southern Hemisphere
8 – 153 Europe	78 – 123 India – China	19 – 64 Africa
128 – 173 Japan	198 – 243 Alaska-Hawaii	139 – 184 Australia-NZ
248 – 293 CONUS	318 – 3 N. Atlantic	259 – 304 South America

The VIRGO™ System also flies one spare satellite per ground track in a sparing orbit designed to make the satellite available to any of the five orbital planes involved with each ground track. The orbital parameters for the spare satellites are given in Table 3.2-1 above

3.3 SYSTEM COVERAGE

The VIRGO™ Constellation ensures visibility from the Earth's surface to an active VIRGO™ satellites 100 percent of the time over the entire Earth pole-to-pole. However, VIRGO™ inherently provides service to land-based fixed terminals. Therefore the VIRGO™ constellation design has been further optimized to provide improved visibility performance, or visibility preference, to all the major continental land masses and important island areas of the Earth, as described and illustrated in Section 3.2 above.

Elevation angles to VIRGO™ satellites always exceed 42 degrees within the Continental United States and Alaska, while always exceeding 30 degrees from the Virgin Islands and Puerto Rico, and 35 degrees from Hawaii.

VIRGO™ exceeds the Commission's requirement for satellite visibilities in all relevant areas of the Earth. However, note that it is not Virtual Geo's intent to provide VIRGO™ service over the entire Earth's surface, but rather to important populated land masses, where VIRGO™ has optimized its performance. The global worst case minimum elevation angle on any significant populated land mass anywhere on the Earth falls to approximately 10 degrees once per 5 hours, and this occurs for less than 0.1% of the Earth's land areas. Minimum elevation angles are below 20 degrees for only 10% of significant populated landmasses and less than 30 degrees for 50% of the areas. However, it should be noted that these areas of low elevation angles are restricted to peripheries of the service areas where the requirement for service is likely to be small, and where the use of lower elevation angles is unlikely to present a problem.

Angular separations between VIRGO™'s active service arc and the geostationary arc from VIRGO™ ground stations average almost 50 degrees and, as stated, always exceed 40 degrees.

VIRGO™ satellites implement two kinds of service over their service areas: single beam and multi-beam. Single beam service supports high data rate user-specific traffic, while multi-beam handles traffic destined simultaneously to many geographically dispersed users within a service area.

The VIRGO™ satellites create user and gateway antenna beams using actively steered phased array antennas so designed and operated as to maintain a given beam on a service area at all times during the satellite's transit of its active arc. This minimizes any requirement for service handoffs from beam to beam, offers a more stable link to the user, and results in greater satellite and link operating efficiencies. Individual beams have a nominal 2.25 degree beamwidth and 38 dBi of peak gain on boresight. Each beam can be steered independently of any other, although in general practice a cluster of beams corresponding to a service area will be steered together in a coordinated fashion. In addition, individual beams can be time-shared over several beam positions to serve larger, lower traffic density areas.

Since all user and feeder link antenna beams are steered in real time toward active markets and users, and may be time-shared among several markets, and will vary in steering as activity varies in real time, it is infeasible to define fixed beam contours.

Multi-beam service uses several individual beams to in effect synthesize a regional or subregional beam. The VIRGO™ System uses real time phase and amplitude control in the feed of a multi-beam signal to multiple beams to continually adjust the resulting beam to cover the relevant market area while minimizing signal directed out-of-area.

Figures 3.3-1 through 3.3-5 present some examples of single beam contour plots for beams directed to the south central United States, New England, Hawaii, and Alaska from the middle of the relevant service arc. Specific beam footprint contour positions for a given target will vary over time as the satellite moves through its arc and as the beam is steered to serve its user community best. In all cases, however, the satellites when active, will occupy a position in space separated from the geostationary arc by at least 40 degrees, thereby protecting GSO satellite services as described later below. TT&C contours are not provided, as the beams are omnidirectional.

Figure 3.3-1: Single Beam Service to South Central United States

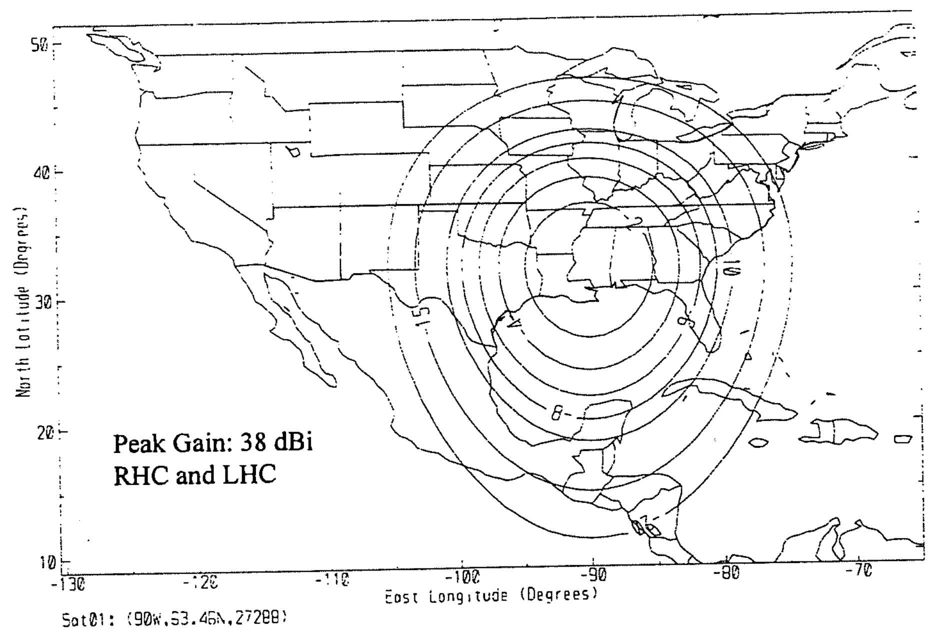


Figure 3.3-2: Single Beam Service to Northeastern United States

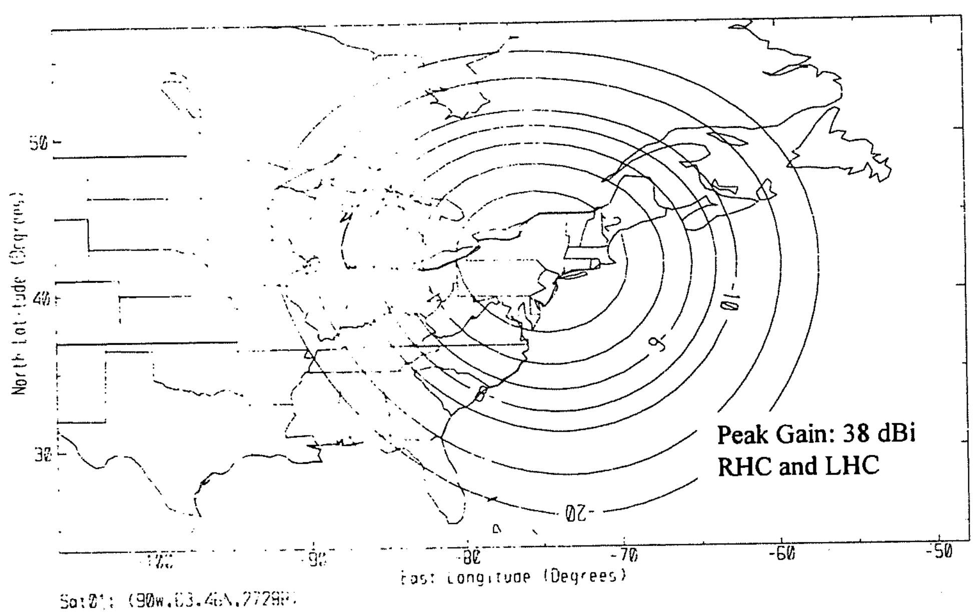


Figure 3.3-3: Single Beam Service to the Northwest United States

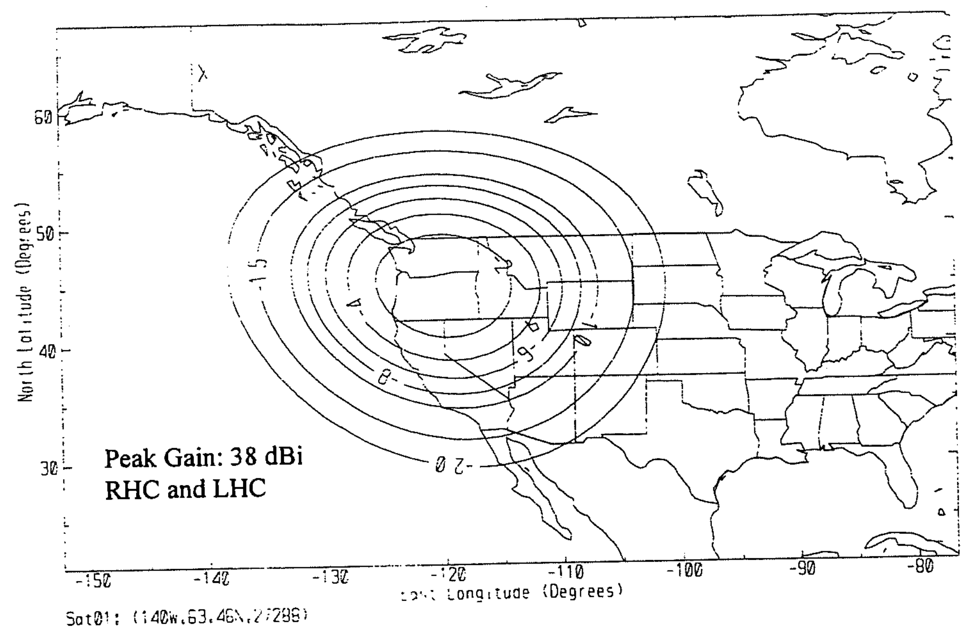


Figure 3.3-4: Single Beam Service to Alaska

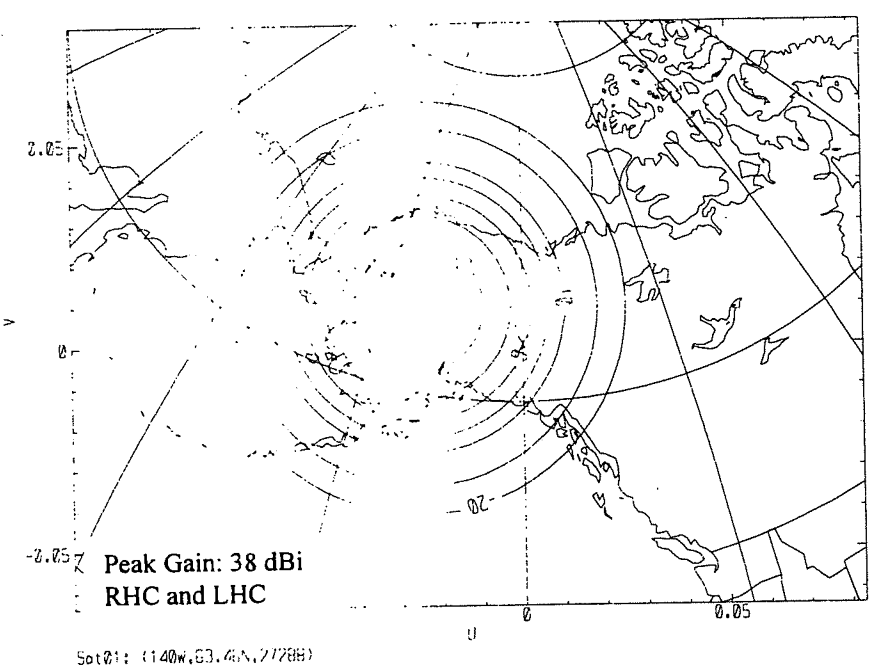
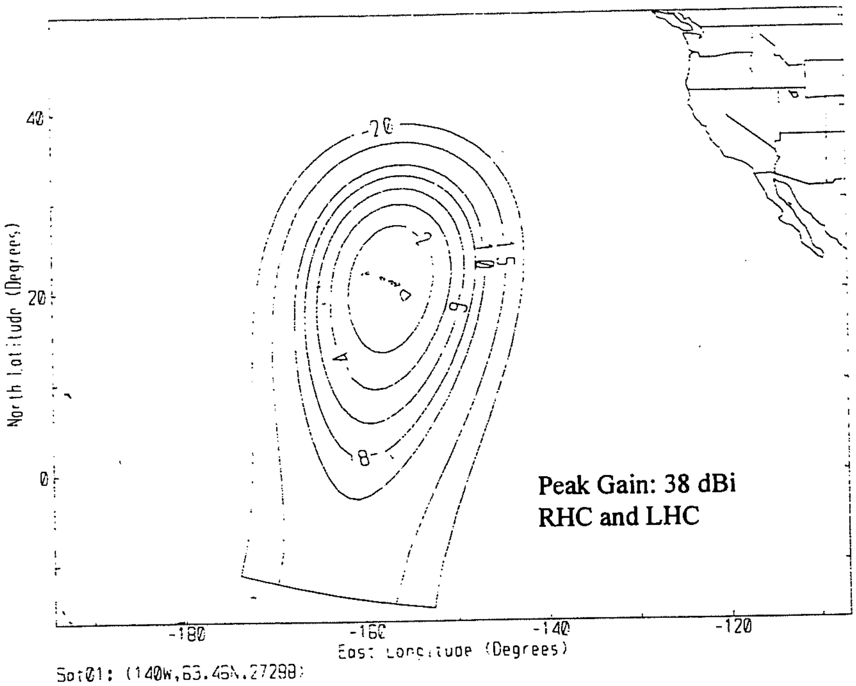


Figure 3.3-5: Single Beam Service to Hawaii



3.4 FREQUENCY AND POLARIZATION PLANS

This application responds to the Commission's Public Notice regarding NGSO FSS systems in the 12.75-13.25 GHz, 13.75-14.5 GHz, 17.3-17.8 GHz and 10.7-12.7 GHz frequency bands.[5] The proposed VIRGO™ system will utilize all these available frequency ranges with the exception of the 13.75 – 13.8 GHz band. In addition, the VIRGO™ system proposes to make use of C-band frequency bands, as detailed below, which are already allocated under the International Telecommunication Union Table of Frequency Allocations to Fixed Satellite-Service ("FSS").

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5 FCC Public Notice Report No. SPB-141 (dated November 2, 1998), "Cut-off Established for Additional Applications and Letters of Intent in the 12.75-13.25 GHz, 13.75-14.5 GHz, 17.3-17.8 GHz and 10.7-12.7 GHz Frequency Bands."

As Virtual Geo explains elsewhere in this Application, it recognizes that the results of ongoing domestic[6] and international[7] regulatory processes may be that some of the frequency bands sought for VIRGO™ are not available to Virtual Geo for the use proposed here. In this event, Virtual Geo will have an opportunity to amend its application to conform to the final frequency band usage scheme.[8]

3.4.1 FCC and ITU Allocations

3.4.1.1 Ku-Band Frequencies

The VIRGO™ system proposes to utilize the 12.75–13.25 GHz (Earth-to-space), 13.8-14.5 GHz (Earth-to-space), 17.3–17.8 GHz (Earth-to-space) and the 10.7–12.7 GHz (space-to-Earth) bands.

In the U.S., incumbent users of the 12.75–13.25 GHz band are the Fixed Service ("FS"), the FSS (Earth–to-space), the Mobile Service ("MS"), and Space Research (deep space), on a co-primary basis. Internationally, the band is allocated to FS, FSS (Earth–to-space) and MS, except for aeronautical mobile, on a primary basis. It is also allocated to Space Research (deep space) (space-to-Earth) on a secondary basis.

In the U.S., incumbent users of the 13.8–14.0 GHz band are the FSS (Earth-to-space), Government Radiolocation and Space Research on a co-primary basis. In addition the Standard Frequency and Time Signal Satellite operates on a secondary basis. Internationally this band is allocated to FSS (Earth-to-space) and Radiolocation on a primary basis and to Standard Frequency and Time Signal-Satellite and Space Research on a secondary basis.

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6 *See Ku-Band NPRM, supra, FCC 98-310, slip op.*

7 ITU-R Joint Task Group 4-9-11 and other related activities leading up to WRC-2000.

8 *See infra* at Sections 1, 11.