United States Patent [19]

Tuck

[54] **METHODS AND APPARATUS FOR AUGMENTING SATELLITE BROADCAST SYSTEM**

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[52] **U.S. Cl.** **455/13.1**; 455/33.2
[58] **Field of Search** 455/33.2, 12.1, 455/13.1, 13.3, 3.2; 342/352, 3; 343/914; 348/6

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,378,837   4/1968   Graves 455/12.1

Primary Examiner—Reinhard J. Eisenzopf
Assistant Examiner—Darnell R. Armstrong
Attorney, Agent, or Firm—Anglin & Giaccherini

[57] **ABSTRACT**

The present invention comprises methods and apparatus for providing programming from both satellites (**11**) and local sources (**L**) using a single receiving antenna (**32**). In a preferred embodiment, beams (**18**) emanating from a geosynchronous satellite (**11**) are collected using the main lobe (**36**) of a home receiving antenna (**32**), while a rebroadcast signal (**26**) generated by an airplane (**20**) circling above the home (**H**) is simultaneously sensed using a side lobe (**38**) of the receiving antenna (**32**). The airplane (**20**) flies along a path (**40**) which is a closed loop so that it is always positioned in a region where the aircraft antenna (**24**) can supply signals (**26**) to the receiving terminal (**28**) using the side lobe (**38**). The present invention may be implemented using any form of airborne platform (**20**), whether it is manned or unmanned. A wide range of methods may be employed to deliberately enhance the sensitivity of the side lobe (**38**) of the receiving antenna (**32**). The invention allows immediate and inexpensive enhancement to existing geostationary broadcast services.
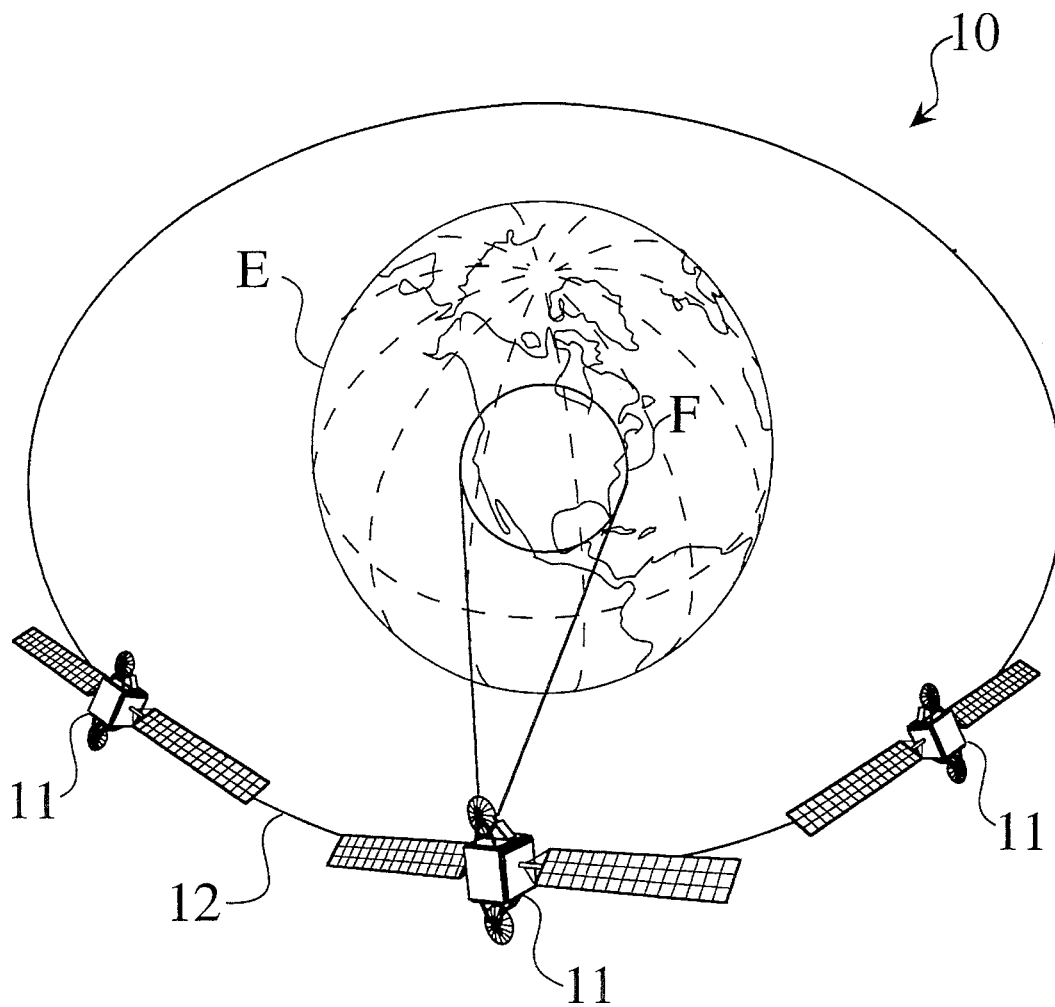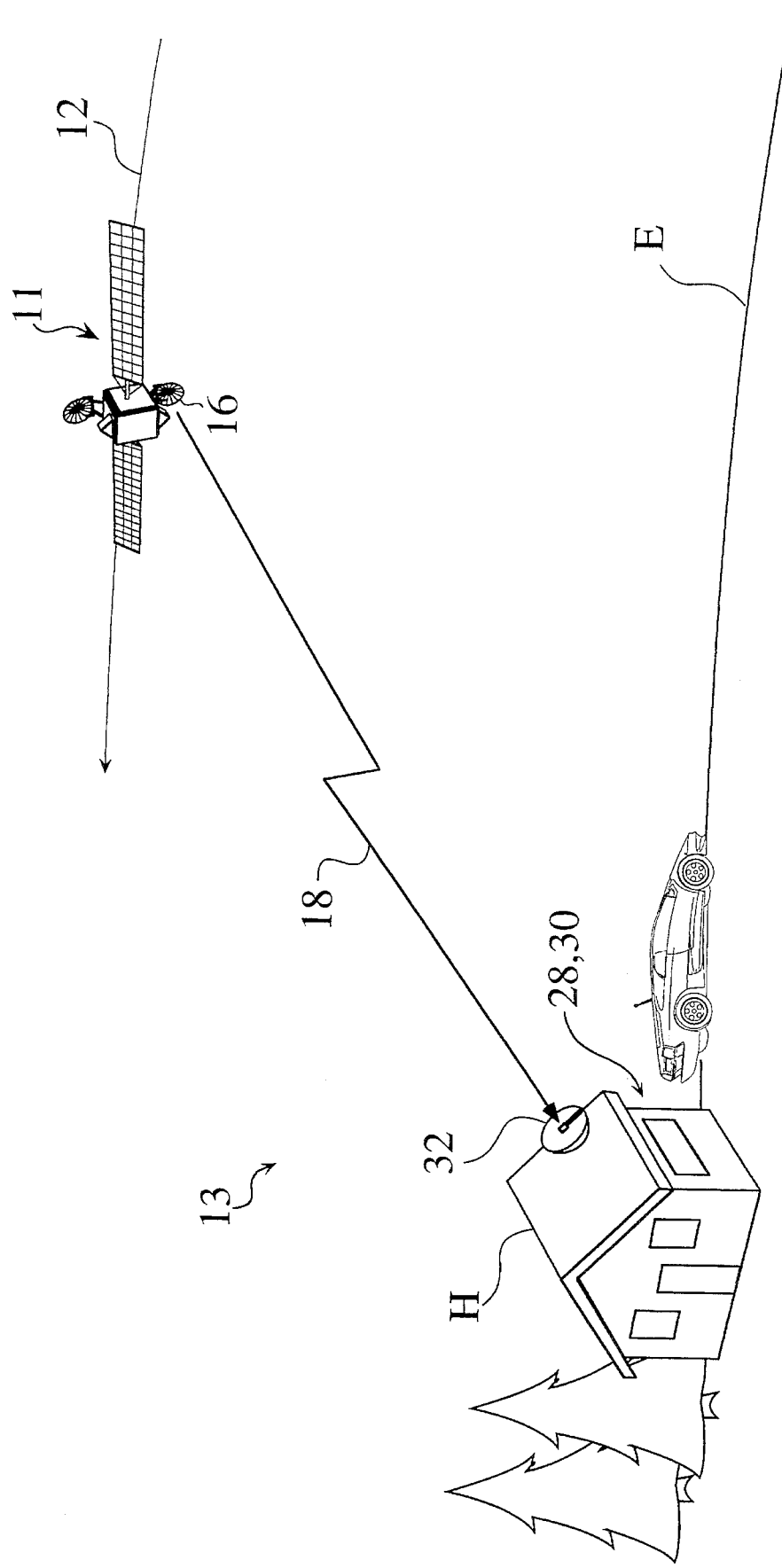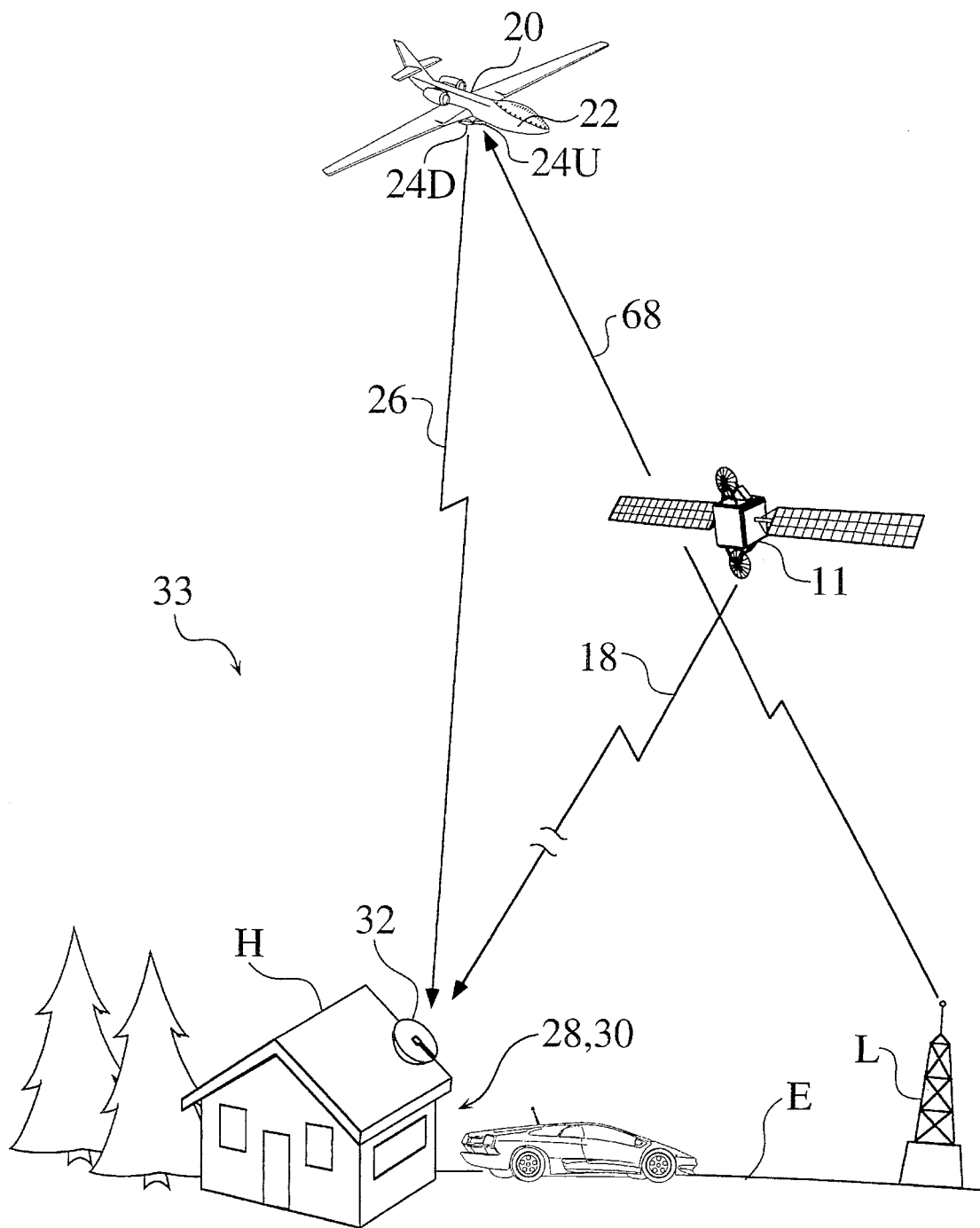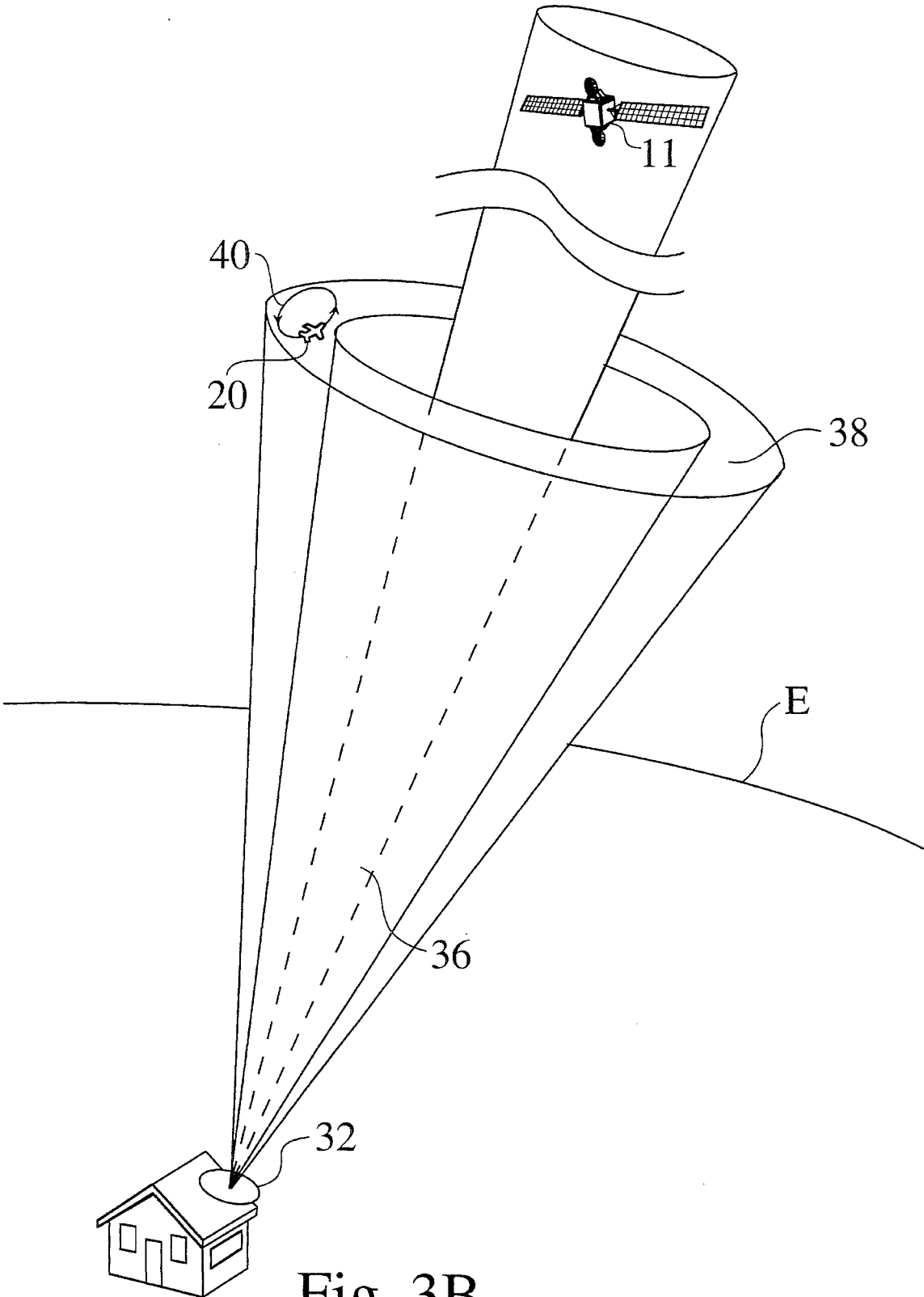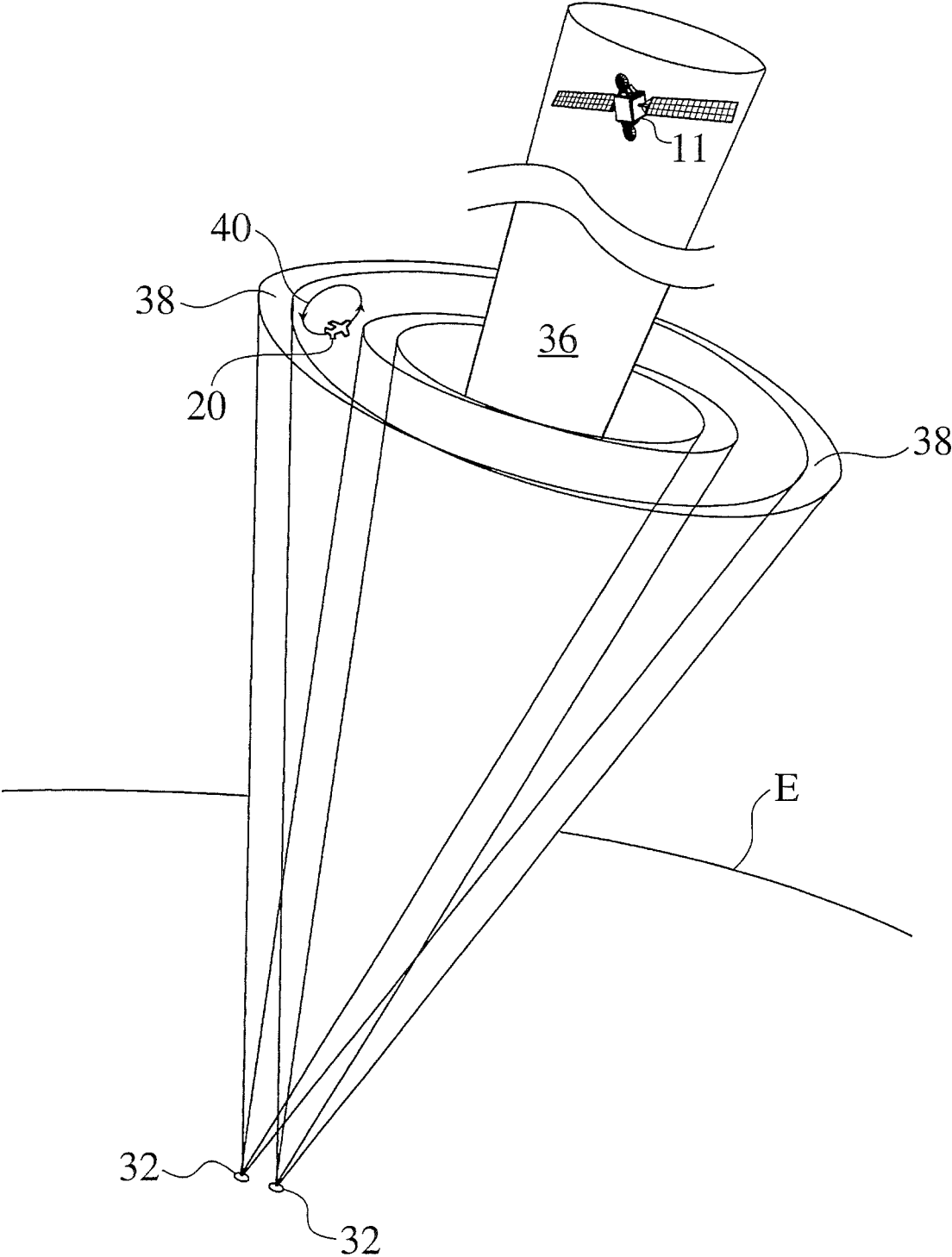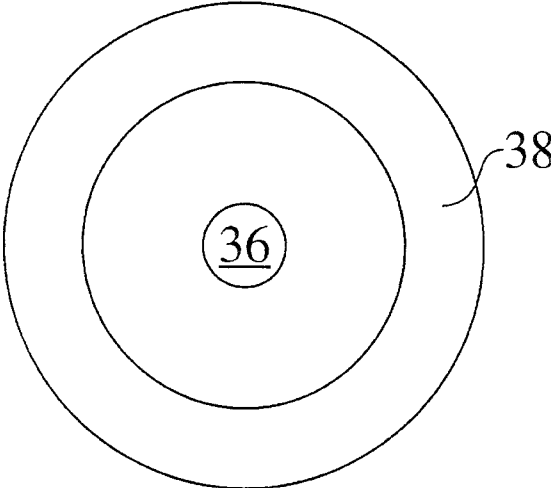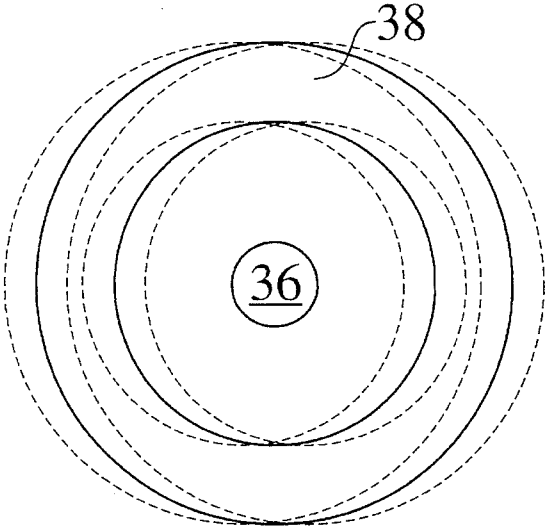
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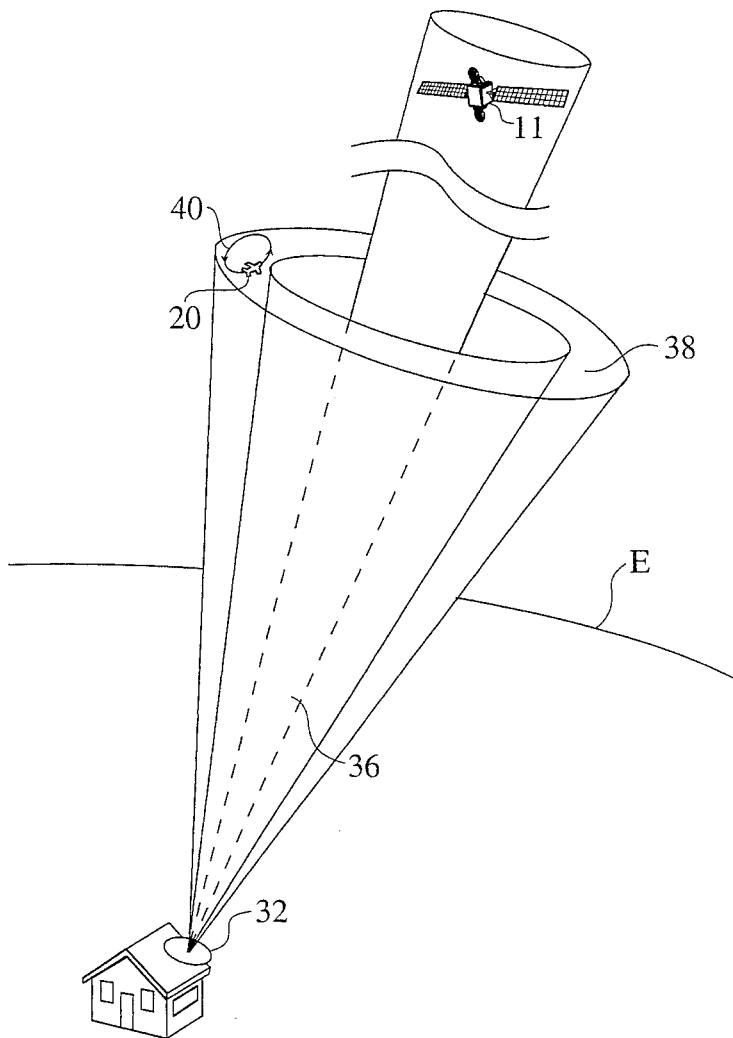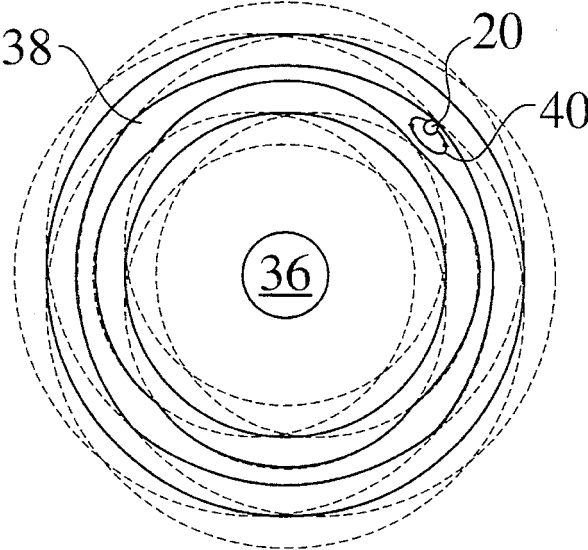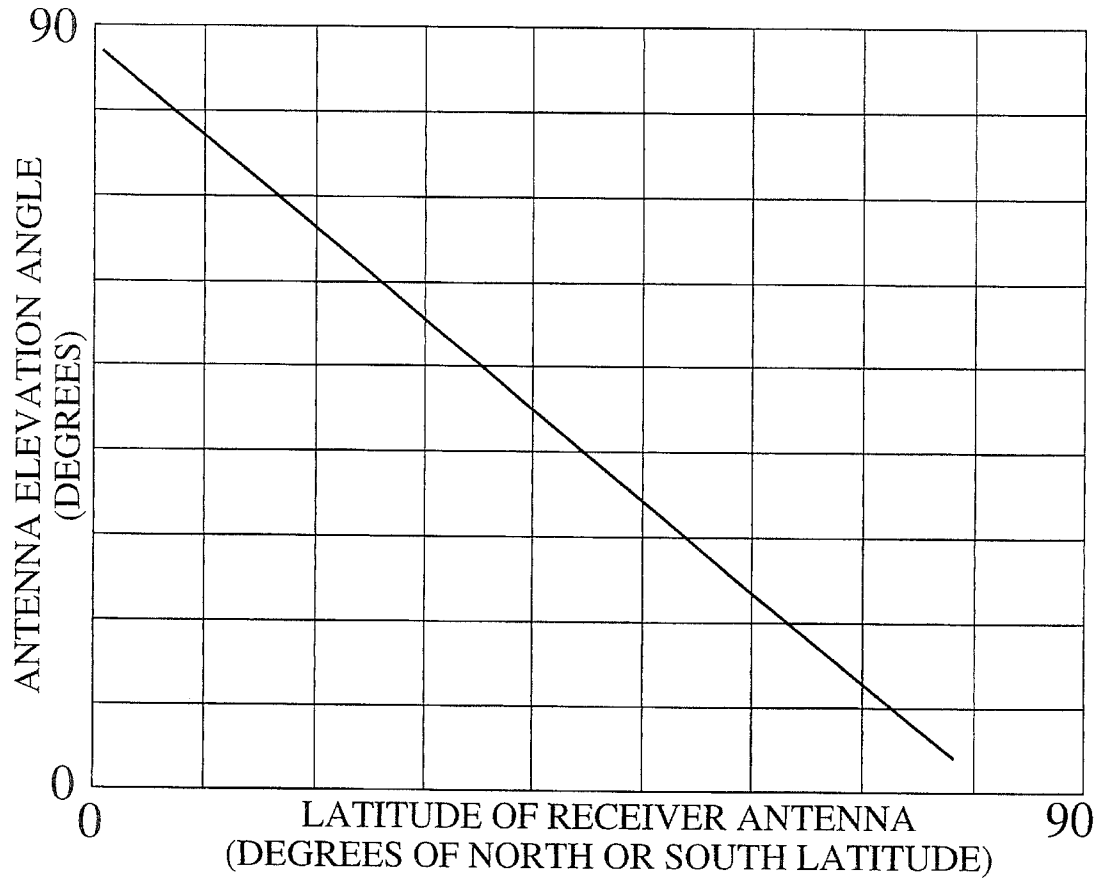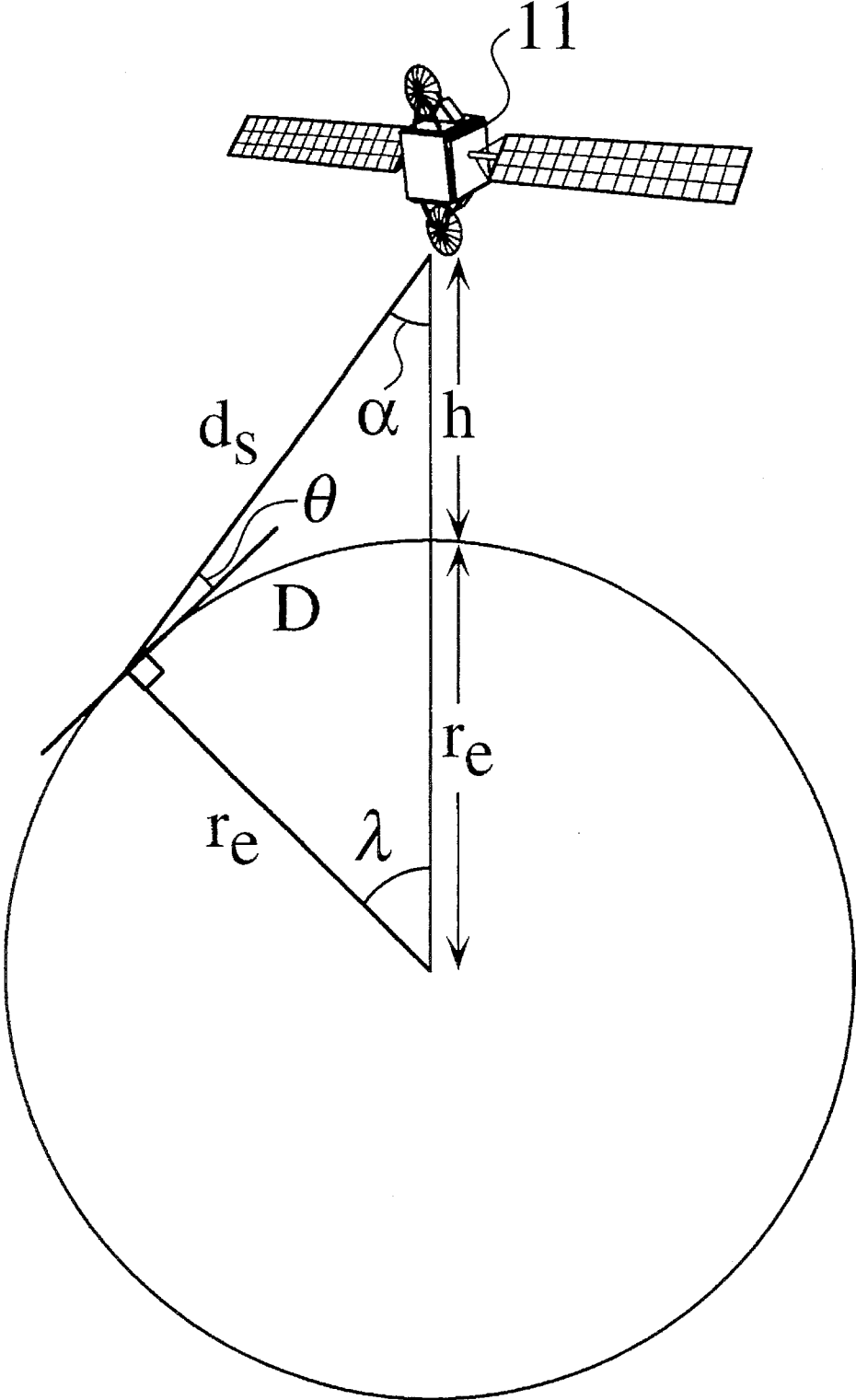
Fig. 1

Fig. 2
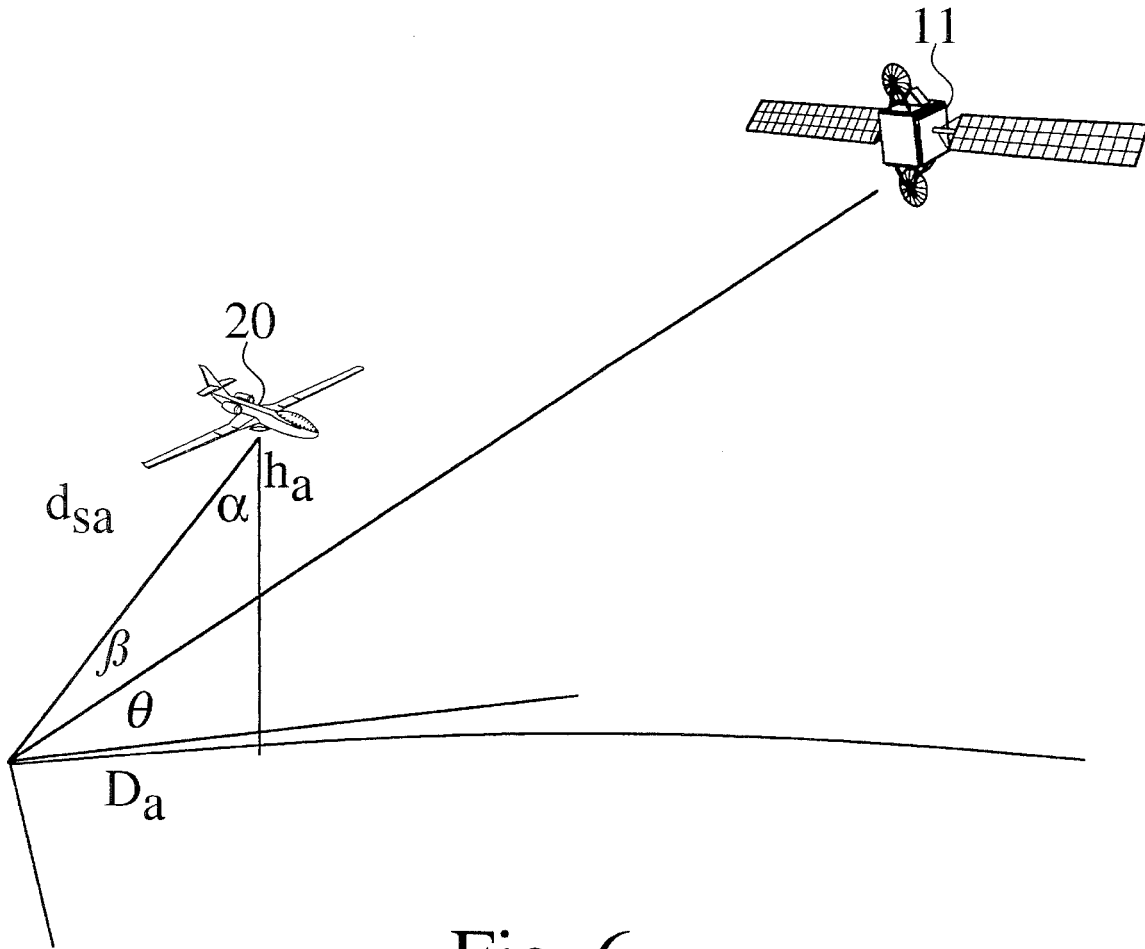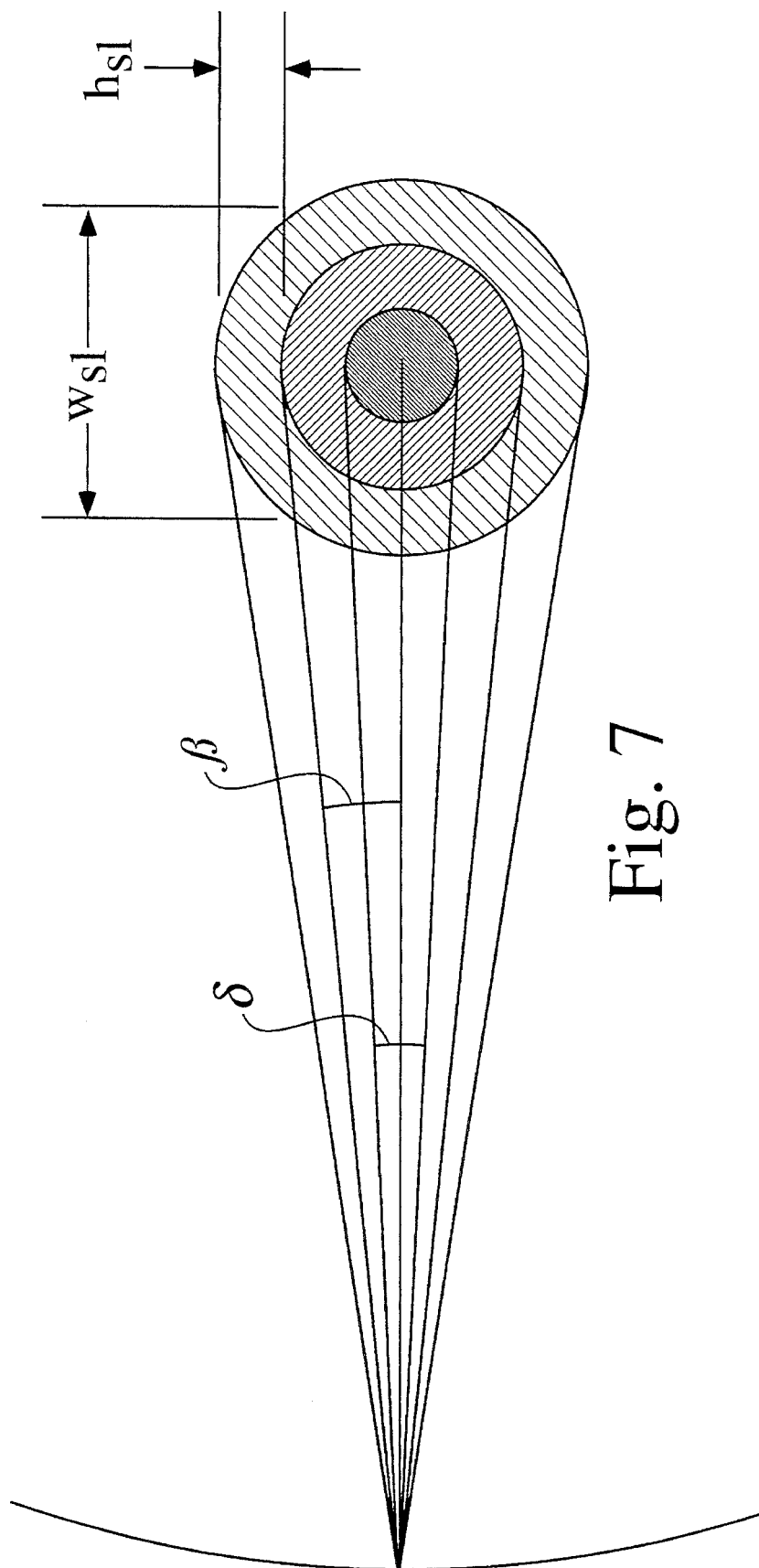
Fig. 3A

Fig. 3B

Fig. 3C

Fig. 3D

Fig. 3E

Fig. 3F

Fig. 4

Fig. 5

Fig. 6

Fig. 7
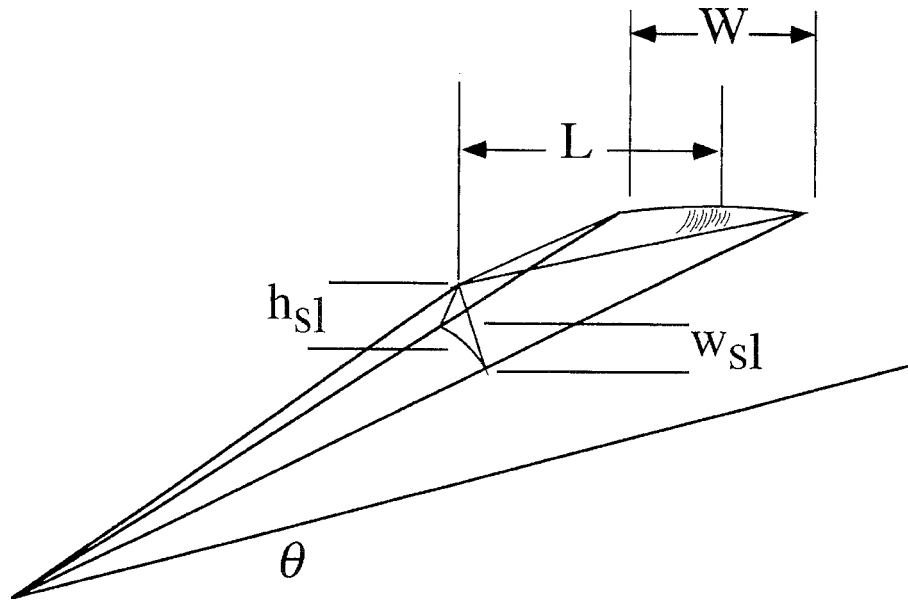
Fig. 8A

Fig. 8B
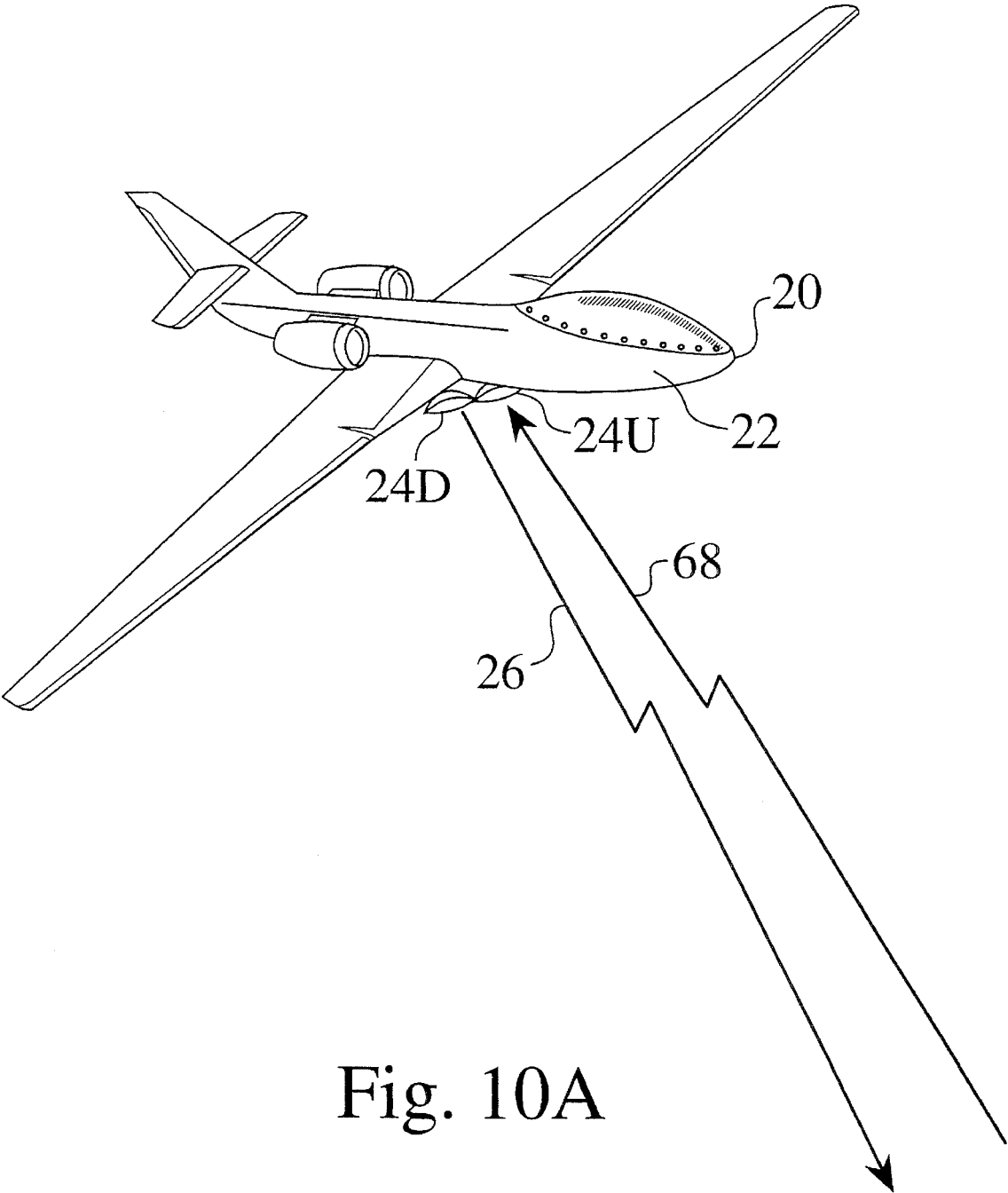
Fig. 9A

Fig. 9B

Fig. 10A

Fig. 10B

Fig. 11

H

32

28

TV

30,64

Fig. 12

37

35
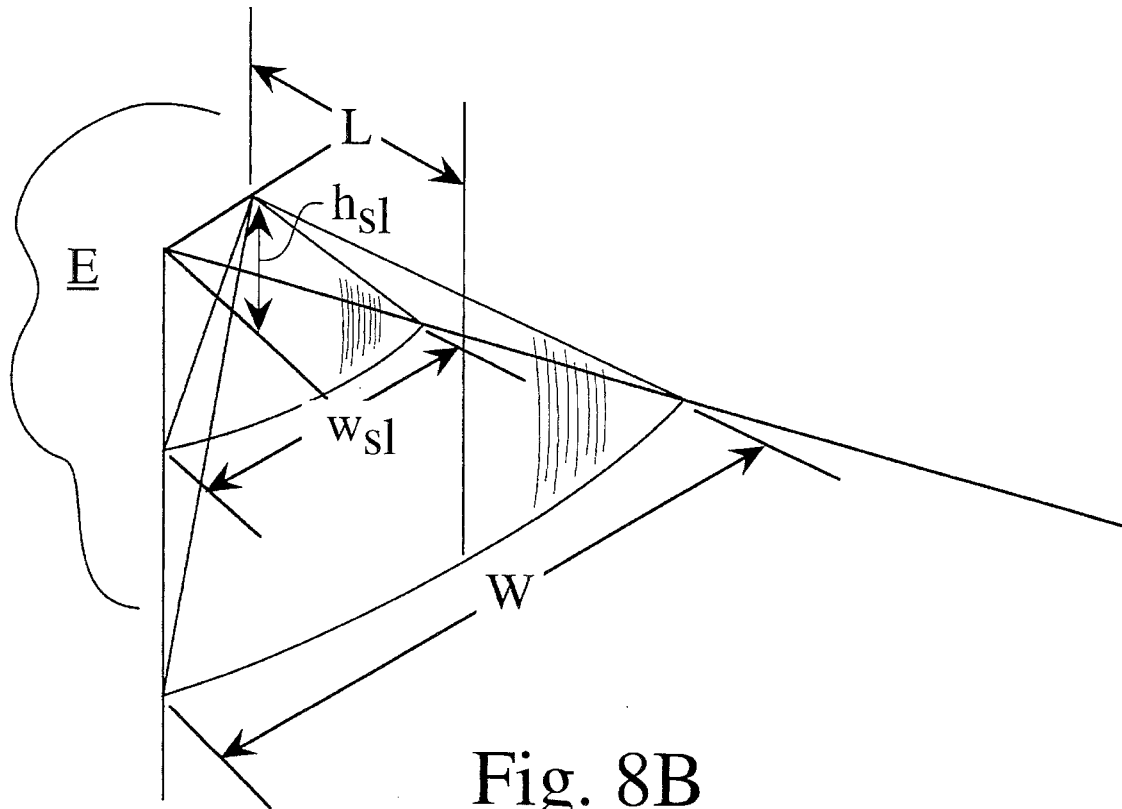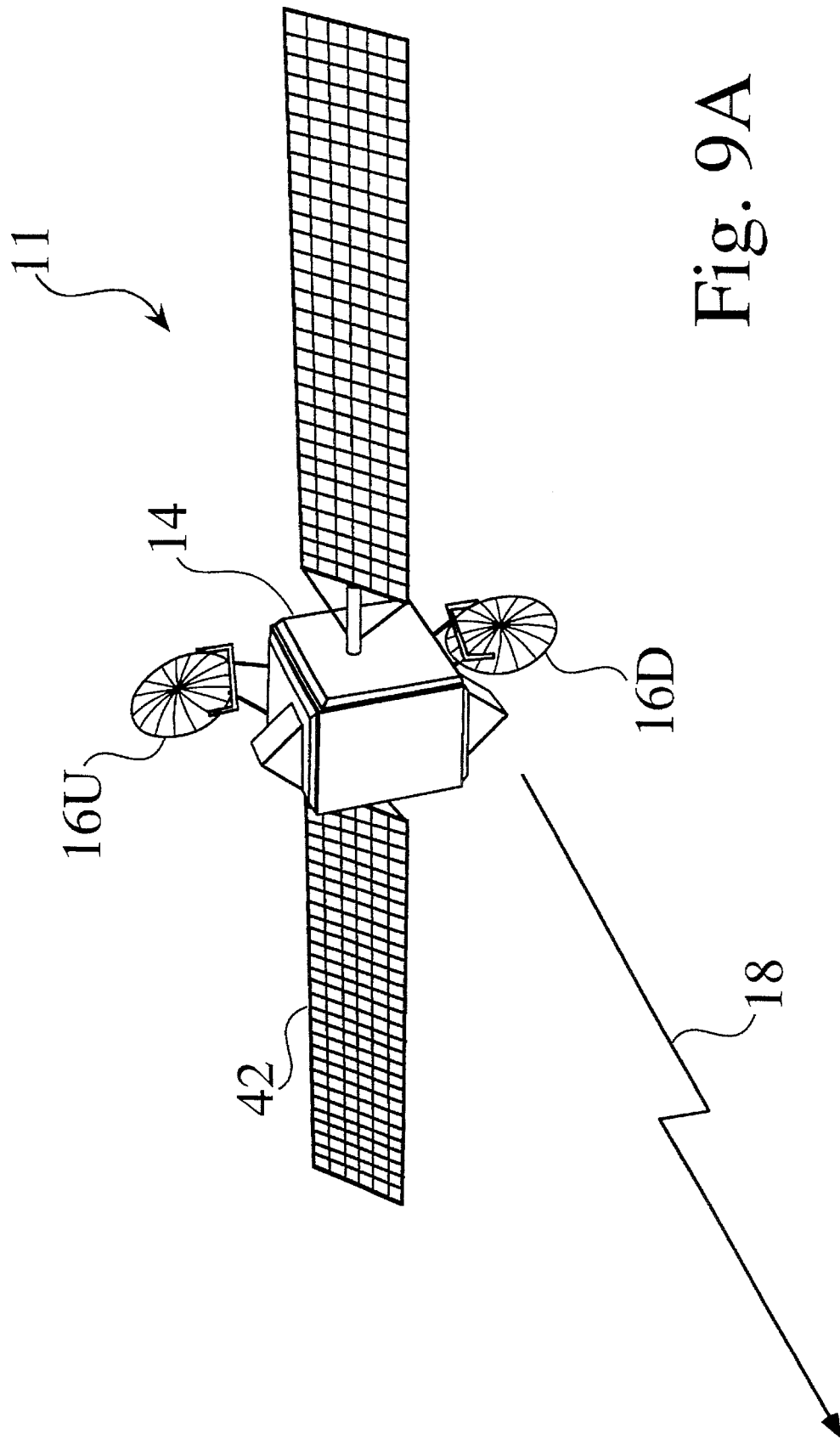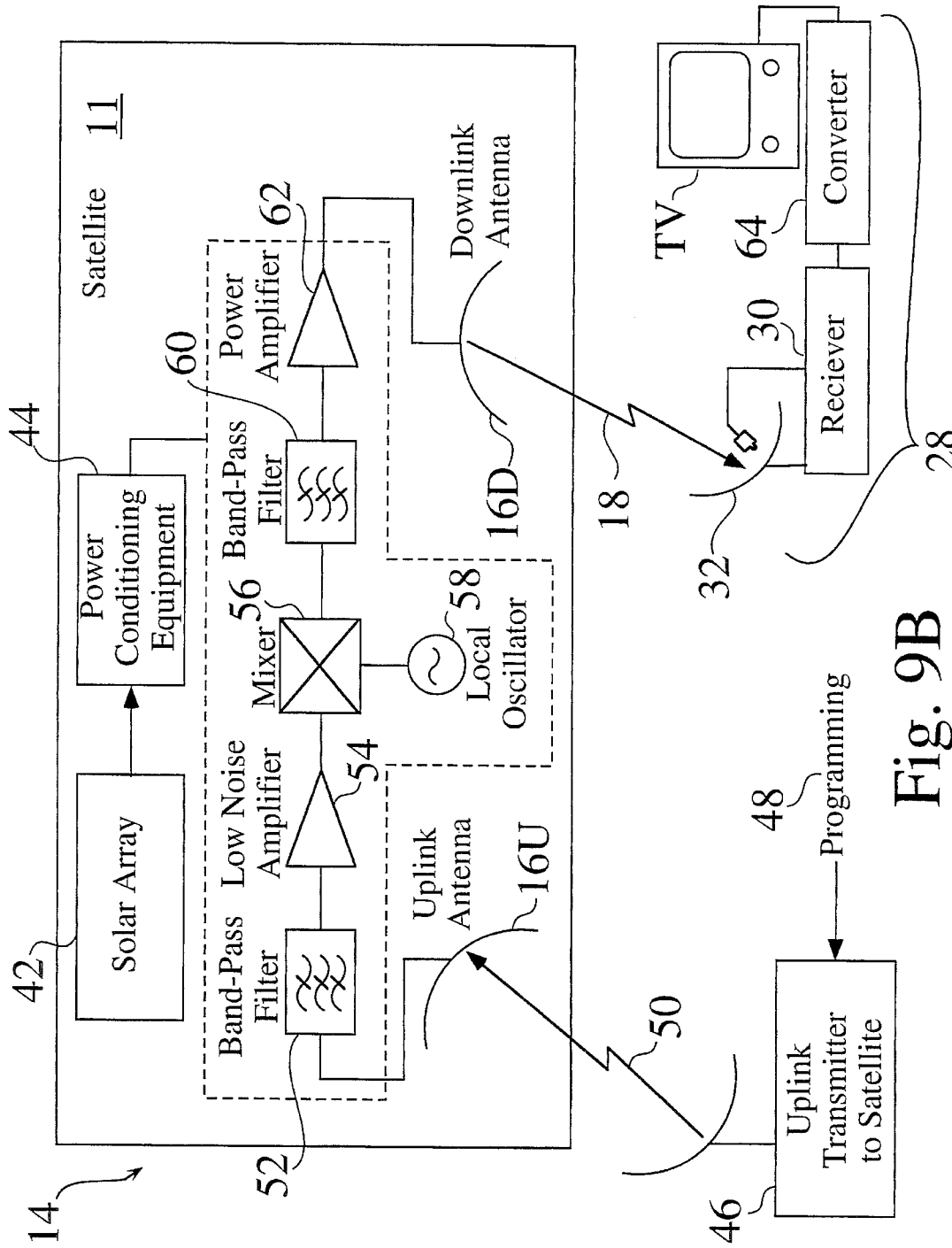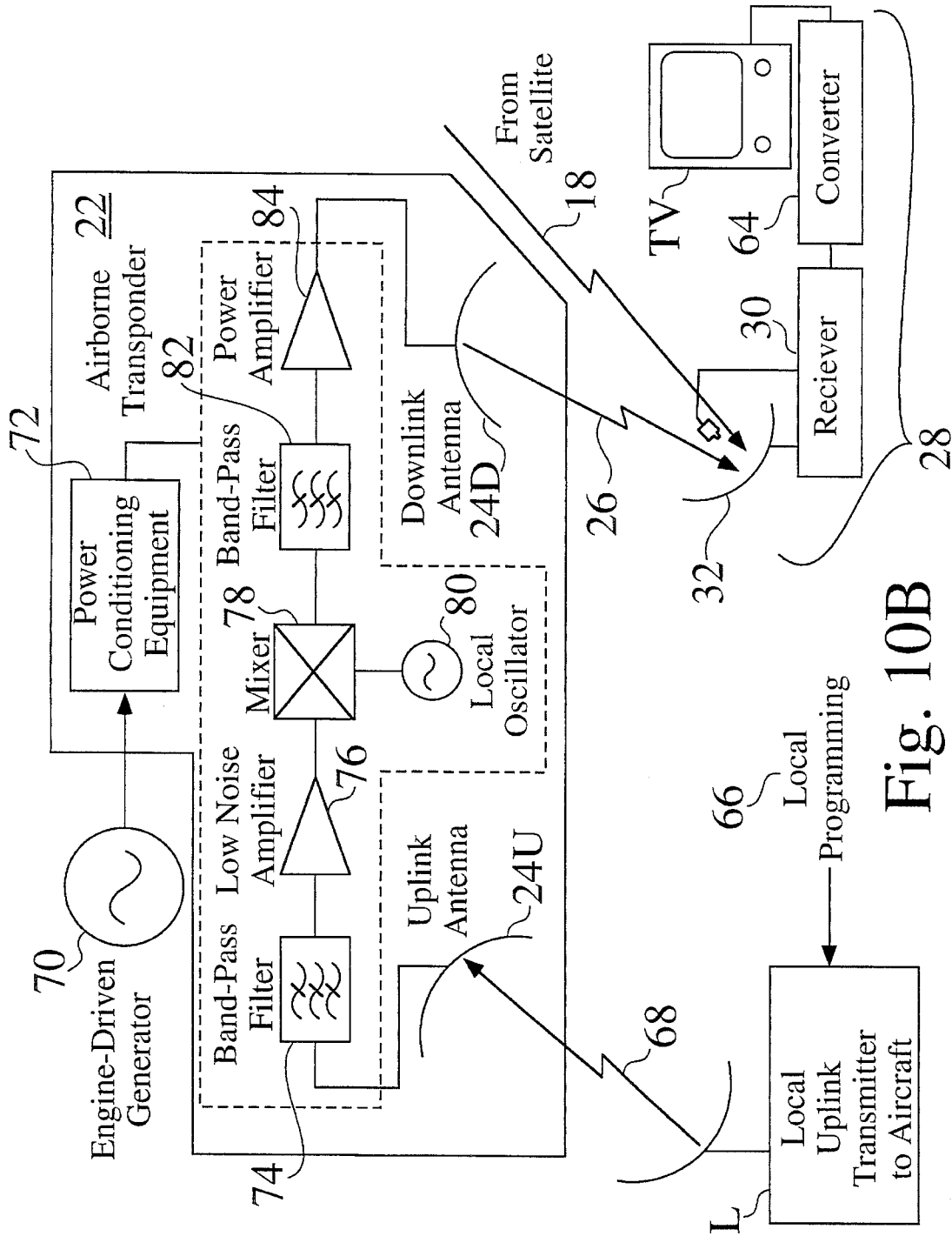
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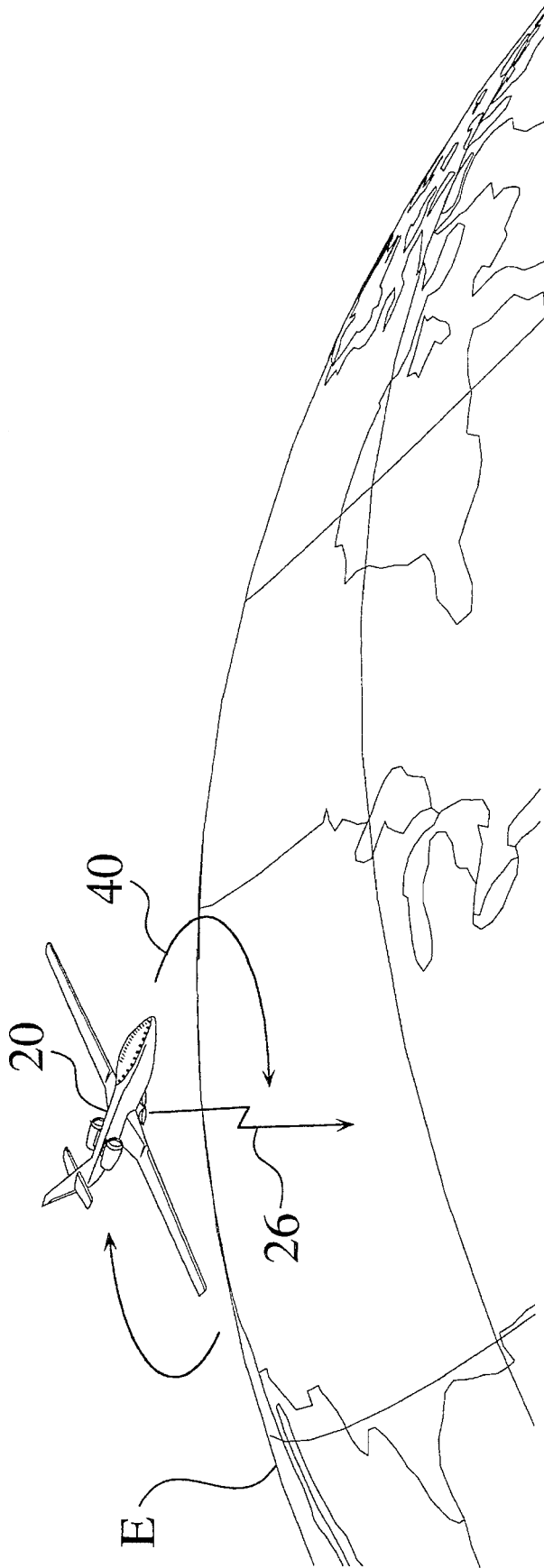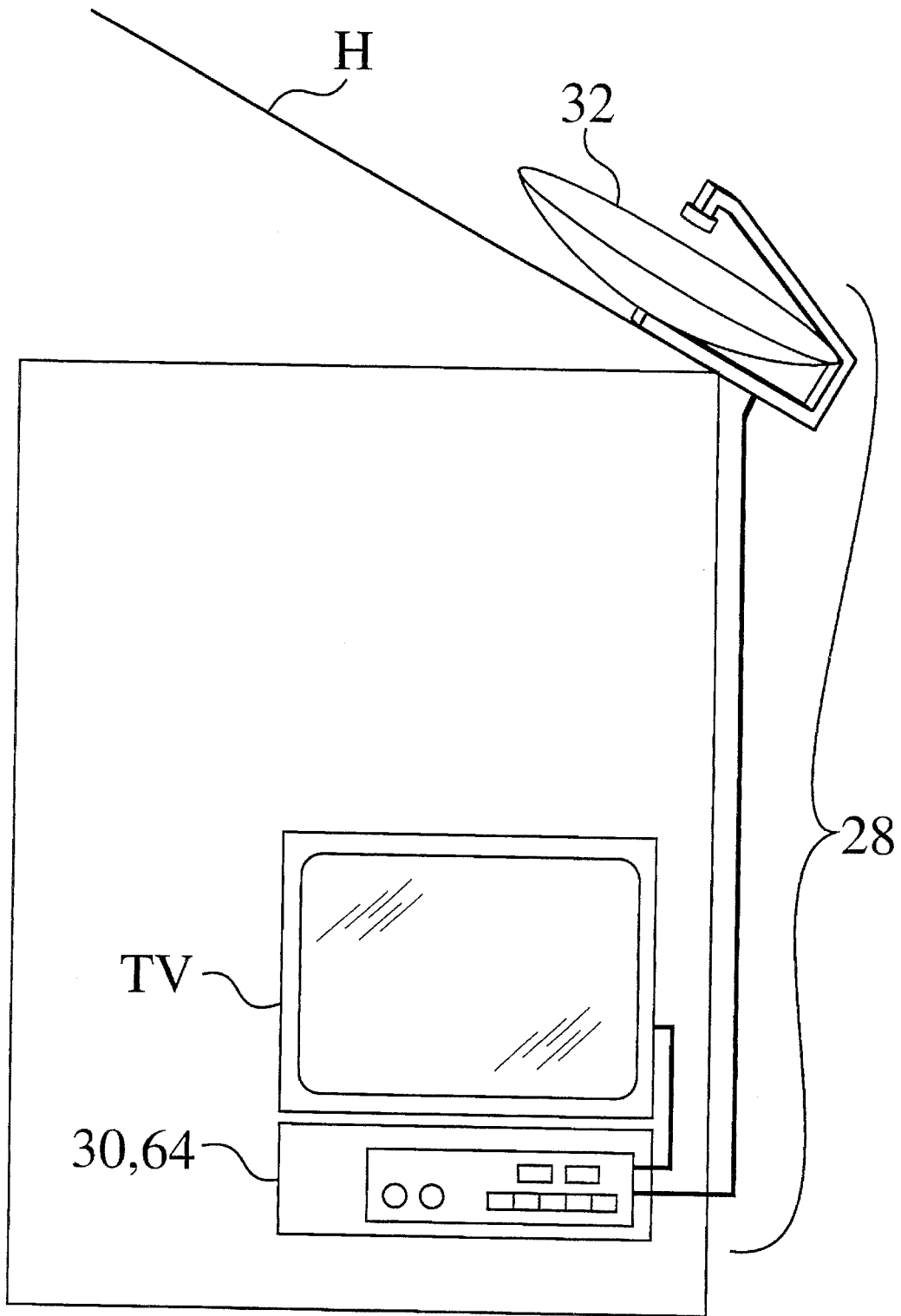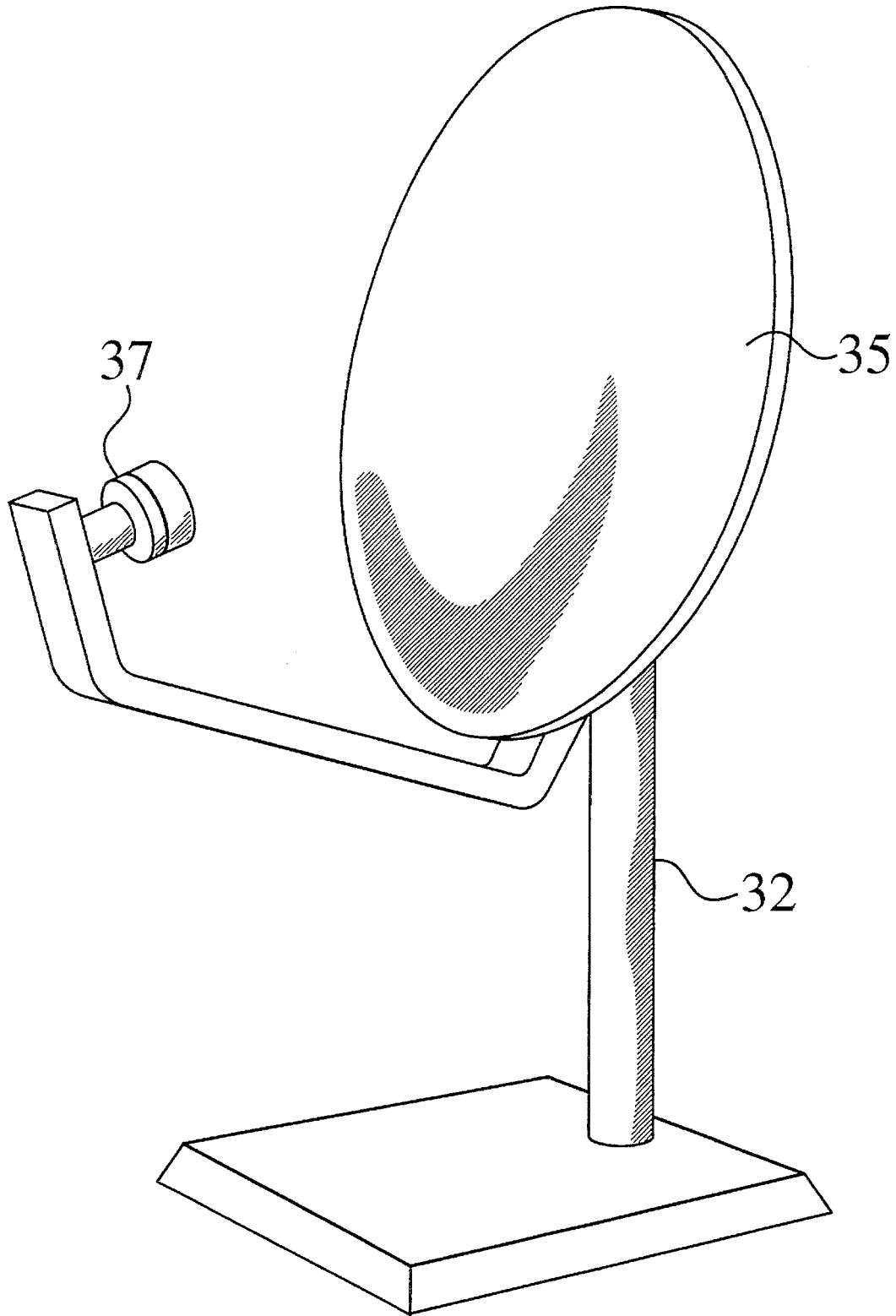## Fig. 13

METHODS AND APPARATUS FOR AUGMENTING SATELLITE BROADCAST SYSTEM

FIELD OF THE INVENTION

The present invention relates to the field of satellite broadcast systems. More particularly, this invention comprises methods and apparatus for receiving direct satellite broadcasts and local programming delivered by an airborne platform using a single receiving antenna.

BACKGROUND OF THE INVENTION

A growing portion of the television programming that is viewed by Americans is broadcast directly to home receivers by geosynchronous satellites. These satellites operate in orbits positioned above the Earth's Equator at an altitude of approximately 22,300 miles. Some consumers use relatively large satellite dishes that may be ten or more feet in diameter to receive television programming directly from satellites such as the Galaxy™ and Telstar™ series of spacecraft. In the past year, receivers that employ much smaller antennas that are only about two feet across have been introduced in the United States. These newer and smaller systems obtain signals from powerful new satellites operated by DirecTV™ and USSB™.

One unfortunate consequence of relying on direct broadcast systems is that they rarely, if ever, provide programming from local stations. One possible solution to this problem would be to use high-altitude airplanes to rebroadcast local television stations in the same frequency band used for direct satellite television broadcasting. The satellites that supply direct broadcast signals move in orbits that are synchronized with the rotation of the Earth. A given geosynchronous satellite therefore appears to be in almost exactly the same elevation and azimuth for all viewers in even a large metropolitan area. In contrast, because the airplane is at a much lower altitude than the geosynchronous satellites used for television broadcasting, it cannot be at the same angle for all viewers.

The problem with this approach is that two different antennas would then be required—one for signals emanating from the satellite, and a second oriented to the airplane's position for signals emitted from the aircraft. The viewer would not only be faced with the higher cost of purchasing two different antennas, but would also suffer the inconvenience of having to constantly switch between the two antennas each time he or she wishes to change channels that are not supplied solely by either the satellite or the aircraft.

Other previous attempts to offer broadcast services from a variety of platforms have been met with mixed results. A number of systems are described in the U.S. Patents cited below.

U.S. Pat. No. 4,392,139, issued to Aoyama et al. in 1983, discloses an omni-directional VHF television antenna system for an aircraft.

U.S. Pat. No. 4,218,702, issued to Brocard et al. in 1980, describes a means for remote control of an aircraft video system for surveying ground activity.

U.S. Pat. No. 3,972,045, issued to Perret in 1976, pertains to an apparatus for transporting and entertaining passengers aboard an aircraft with a television system.

U.S. Pat. No. 3,778,007, issued to Kearney, II et al. in 1973, concerns a rod television-guided drone to perform reconnaissance and ordnance delivery.

U.S. Pat. No. 3,406,401, issued to Tillotson in 1968, discloses a synchronous satellite communication system for communicating simultaneously with a number of ground stations.

U.S. Pat. No. 2,748,266, issued to Boyd in 1956, describes a radiant energy relay system having mobile relay signaling stations moving in continuously progressing succession.

U.S. Pat. No. 2,626,348, issued to Nobles in 1953, relates to radio systems employing equipment mounted on aircraft for re-transmitting or relaying programs.

U.S. Pat. No. 2,598,064, issued to Lindenblad in 1952, discloses the transmission of radio signals between remote points.

U.S. Pat. No. 2,509,218, issued to Deloraine in 1950, pertains to a radio multi-channel communicating system adapted for association with predetermined routes.

U.S. Pat. No. 4,253,190, issued to Csonka in 1981, describes a communications system using a mirror kept in outer space by electromagnetic radiation pressure.

U.S. Pat. No. 5,133,081, issued to Mayo in 1992, discloses a remotely controllable message broadcast system including central programming station, remote message transmitters and repeaters.

This problem of designing a system which provides programming from both satellites and local sources without utilizing two different antennas has presented a major challenge to the satellite business. The development of a home receiver that is capable of supplying both local and satellite signals but which is also relatively inexpensive and easy to use would constitute a major technological advance and would satisfy a long felt need within the television and communications industries.

SUMMARY OF THE INVENTION

The present invention is a system which provides programming from both satellites and local sources using a single antenna. Television or other signals are transmitted to receivers primarily intended for use with geostationary satellites, without modification to those receivers or their antennas. An airplane is positioned off-axis to the receiving antennas so as to transmit signals into the antennas' side-lobes. The invention allows immediate and inexpensive enhancement to existing geostationary broadcast services.

In a preferred embodiment, beams emanating from a geosynchronous satellite are collected using the main lobe of a home receiving antenna, while a rebroadcast signal generated by an airplane circling above the home is simultaneously sensed using a side lobe of the receiving antenna. The airplane flies along a path which is a closed loop so that it is always positioned in a region where the aircraft antenna can supply signals to the receiving terminal using the side lobe. The present invention may be implemented using any form of airborne platform, whether it is manned or unmanned.

This approach offers a convenience to the viewer, in that he or she does not need to disconnect his television receiver from the satellite receiver and connect it to a local antenna or cable system to receive local news and other local programming. If the airborne broadcast is provided by the satellite broadcast entity, the service provided would be indistinguishable from terrestrial cable service, except possibly for higher quality. The subscriber might also be able to avoid the additional cost of local terrestrial cable service, if his or her primary reception were poor.

An appreciation of other aims and objectives of the present invention and a more complete and comprehensive understanding of this invention may be achieved by studying the following description of a preferred embodiment and by referring to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of geosynchronous satellites in Earth orbit.

FIG. **2** is a schematic diagram that illustrates a geosynchronous satellite transmitting signals to a receiving antenna mounted on the roof-top of a home.

FIG. **3A** is a schematic diagram which reveals the preferred embodiment of the present invention. The same receiving antenna shown in FIG. **2** is used to receive both direct satellite broadcasts and signals transmitted from a local airborne platform.

FIGS. **3B** and **3C** are schematic illustrations which show the relationships among the satellite, the airborne platform and receiving antennas. For the sake of simplicity of the drawing, the satellite and the airborne platform are displayed close together on the same page, even though they are actually located at vastly disparate altitudes. These two schematic figures are intended to reveal the basic geometry of the main and side lobes of receiving antennas as they relate to the airborne platform and the satellite.

FIGS. **3D**, **3E** and **3F** present cross-sections of the main and side lobes of a receiving antenna at the altitude of the airborne platform.

FIG. **4** is a graph which plots antenna elevation pointing angle versus the geographical latitude of the receiving antenna.

FIGS. **5** and **6** are schematic, unscaled drawings which depict geometrical relationships among a direct broadcast satellite, a local airborne platform and a receiving antenna on the Earth's surface.

FIG. **7** supplies a view of a receiving antenna pattern, and includes a depiction of both the main and side lobes of the antenna.

FIGS. **8A** and **8B** illustrate the geometry of the projection of the upper portion of the side lobe which lies in the plane of the altitude of the airborne platform.

FIG. **9A** is a schematic view of a satellite that may be employed to practice the present invention.

FIG. **9B** presents a schematic block diagram of a satellite-borne television transponder.

FIG. **10A** is a schematic view of an aircraft that may be utilized to implement the present invention.

FIG. **10B** is a schematic block diagram of an aircraft-borne television transponder.

FIG. **11** shows the aircraft depicted in FIG. **10** flying in a generally circular flight path.

FIG. **12** is a schematic view of a direct broadcast satellite terminal, which includes a receiver and an antenna.

FIG. **13** is a perspective view of a receiving antenna.

DETAILED DESCRIPTION OF PREFERRED AND ALTERNATIVE EMBODIMENTS

Geosynchronous Direct Broadcast Systems

FIG. **1** furnishes a schematic view **10** of satellites **11** operating in geosynchronous orbit **12** above the Earth E. Each satellite **11** travels along an orbit **12** which is positioned above the Equator, and emits signals that form a footprint F on the surface of the Earth. FIG. **1** is not drawn to scale. For the sake of simplicity, none of the figures which accompany this Specification that portray the relative locations of satellites or aircraft are drawn to scale.

FIG. **2** is a schematic illustration **13** of a satellite **11** that includes a transponder **14** and antennas **16**. Satellite beams of radiation **18** are emitted from the antennas **16** down to a home H and provide television programming to a terminal **28** which includes a receiver **30** and a paraboloidal reflector antenna **32**.

A Preferred Embodiment of the Invention

FIG. **3A** is a third schematic view **33** that portrays a preferred embodiment of the present invention. An aircraft **20** flying over a home H is employed to rebroadcast local programming to a terminal **28** inside the home using the same receiver antenna **32** that is already utilized to acquire signals **18** from the satellite **11**. In the preferred embodiment of the invention, the manned aircraft **20** includes a transponder **22** and antennas **24U** and **24D** which relay signals **26** to consumers.

Like all antennas, the paraboloidal reflector antenna **32** has a "main lobe" in which almost all of the radio-frequency energy received or sent by the antenna is contained. This main lobe **36** is generally from one to a few degrees in diameter, is approximately circular in cross-section and is on or near the central axis **34** of the reflector antenna **32**.

As is also the case with all other antennas, the receiver antenna **32** has a series of unwanted responses, called "side lobes" These side lobes **38** are annular in cross-section, are centered roughly on the main lobe **36** and are separated from the main lobe **36** by angles that depend on the design of the antenna. There are several of these side lobes **38**. In antennas used for receiving, the strongest response is in the side lobe nearest the main lobe (the "first side lobe"), and successively weaker responses occur in side lobes that are more widely separated from the main lobe. In a typical parabolic or paraboloidal-reflector antenna, the first side lobe is located at an angle to the main lobe of about four to six degrees, and its response is of the order of 20 to 30 decibels less than the main lobe.

FIG. **3B** is a schematic drawing which shows a satellite **11** operating in a conical region of space that corresponds to the main lobe **36** of a receiving antenna **32**. A rebroadcast signal **26** emitted by the aircraft is simultaneously sensed by the receiver antenna **32** using a side lobe, which is shown as a region of annular cross-section, labeled "**38**", coaxial to the main lobe **36**. The response of the antenna to signals originating in the region of the annular cross-section between main lobe **36** and side lobe **38** is very slight. The aircraft **20** flies along a path **40** such as a circle or a closed loop within the region of annular cross-section that defines the side lobe **38**. In the preferred embodiment, the path **40** is a "racetrack" pattern. The aircraft **20** is always positioned in the region of annular cross-section where the aircraft downlink antenna **24D** can supply signals to the terminal **28** using the side lobe **38**. The present invention may be implemented using any form of airborne platform **20**, whether it is manned or unmanned.

FIG. **3C** is similar to FIG. **3B**, but reveals how the aircraft **20** flies in an "overlap" region that occupies a zone which corresponds to the intersected spaces of the side lobes **38** of more than one receiving antenna **32**. In the preferred embodiment of the invention, the airplane **20** is positioned

over a densely populated area so that it can provide signals to many receiving antennas **32**.

FIGS. **3D**, **3E** and **3F** depict cross-sections of the main and side lobes **36** and **38** of the receiving antenna **32** at the altitude of the circling aircraft **20**. FIG. **3D** is a picture of a single antenna pattern. The circular cross-section of the main lobe **36** is situated at the center of this single antenna pattern, while the annular cross-section of the side lobe **38** is located at the periphery of the pattern.

FIG. **3E** supplies an illustration of three superimposed overlapping antenna patterns like the single pattern shown in FIG. **3D**. The two patterns shown in dashed lines in FIG. **3E** are slightly offset from the center pattern along an East-to-West axis. FIG. **3F** is similar to FIG. **3E**, but adds two more antenna patterns that are offset from the center pattern along the North-to-South axis. FIGS. **3E** and **3F** are intended to demonstrate how the side lobes **38** of a number of receiving antennas **32** form an overlapping region or zone in the atmosphere. This overlapping region is the space where the aircraft **20** flies its closed loop pattern **40**, as indicated in FIG. **3F**.

Geometrical Relationships Among Satellites, Aircraft and the Receiver Antenna

Since the geosynchronous satellites **11** are of necessity directly above the Equator, and all receiving antennas **32** of terminals **28** which are intended to receive signals from a geosynchronous satellite must point their main lobes **36** at the satellite **11**, it follows that all antennas aimed at a geosynchronous satellite must point their main lobes **36** upward at an angle θ which depends on the latitude L of the antenna **32**. The main lobes **36** must also be pointed sideward an angle to the local meridian determined by the position of the satellite in its Equatorial orbit, which position is regulated by Government authorities, and which must remain fixed with respect to the Earth's surface. The latitude L(θ) of a particular elevation angle (θ) of the antenna is determined from the expression presented by Equation One:

$$L(\theta)=(\arccos(0.1510*\cos(\theta)))-\theta \qquad \text{Equation 1}$$

where θ is in degrees.

FIG. **4** presents a graph **42** which plots the antenna elevation pointing angle θ versus latitude L(θ).

The United States of America lies between approximately 24 degrees north latitude and 48 degrees north latitude, resulting in antenna elevation angles of about 36 degrees, in the north of Maine, to about 63 degrees in South Texas. The airplane **20** can be flown in an area that is sufficiently distant from metropolitan areas, and at an appropriate azimuth and elevation from the main beams of the receivers in that metropolitan area, to intersect the first side lobes **38** of most of the receiver antennas **32** in the metropolitan area. The minimum horizontal distance from the airplane **20** to the receiver antenna **32** is given by the expression:

$$D*h=a*\cot(\theta+\alpha) \qquad \text{Equation 2}$$

where a is the altitude of the airplane.

In a preferred embodiment of the invention, the airplane **20** flies at 50,000 feet above the surface, and its average horizontal distance from the receiving antennas **32** will range from 12 miles in Maine to 5.4 miles in south Texas. In this embodiment, the "top" of the first sidelobe **38** is utilized. The aircraft **20** may be flown in a region that is sufficiently distant from a metropolitan area, and at an

appropriate azimuth from the main lobes **36** of the receiver antennas **32** in that metropolitan area, to intersect the first side lobes **38** of most of the receiving antennas **32** in the metropolitan area.

The free-space attenuation of the received signal is proportional to the square of the path length. The slant range to a geostationary satellite varies with latitude, but is generally about 24,000 miles. Even if the airplane is as far as fifty miles from a receiver, the received signal from the airplane is 10 log (25,000/50) =27 decibels stronger, other things being equal. This level of signal strength more than makes up for the lower sensitivity of the receiver antenna **32** at the side lobe angle.

FIG. **5** exhibits the geometrical relationships between a satellite **11** and a receiving antenna **32**. The constants and variables depicted in FIG. **5** are specified below:

r_e = Earth's radius =	6378 kilometers
h (geosynchronous) =	35860 kilometers
h_a = Airplane's altitude =	50,000 feet (15.24 km)
β = First sidelobe offset =	4.5 degrees
δ = Beamwidth =	3 degrees
α = Airplane's or satellite's lookdown angle	
d_s = Slant range	
D = Surface distance from nadir	
λ = Latitude difference	
θ = Look angle	

For a geosynchronous satellite, the slant range d_s and elevation (look angle) θ as seen from the subscriber's antenna varies with the subscriber's latitude as follows:

From the law of cosines:

$$d_s^2=r_a^2+(r_a+h)^2-2r_a(r_a+h)\cos\lambda \qquad \text{Equation 3}$$

From the law of sines:

$$\theta=\arccos(-(\sin\lambda)*(h+r_e)/d_s) \qquad \text{Equation 4}$$

For latitudes ranging from thirty to fifty degrees, Equation 4 produces the values presented in Table One:

TABLE One

Latitude	30	35	40	45	50
d_s	36853	37194	37194	37576	37997
θ	55.00	49.4	43.7	38.2	32.7

FIG. **6** depicts the geometrical relationships between the receiving antenna, the airplane and the satellite. For an airplane at an altitude h_a, the slant range d_{sa} and the surface distance D_a from the subscriber to the airplane may be calculated as follows:

$$\alpha=\arcsin(r_e*\sin(b+\theta+90)/(h_a+r_e)) \qquad \text{Equation 5}$$

$$\lambda=180-(\alpha+\beta+\theta+90) \qquad \text{Equation 6}$$

$$D_a=\pi*r_e*\lambda/180, \text{ approximately } h_a/\tan(\theta+\beta) \qquad \text{Equation 7}$$

Table Two presents the appropriate values of α, λ, d_{sa} and D_a for the case when the airplane **20** is centered in the top of the first side lobe **38**:

TABLE Two

α degrees	30.4	36.0	41.6	47.2	52.6
λ degrees	0.08	0.10	0.12	0.15	0.18

TABLE Two-continued

d_{sa} kilometers	17.7	18.9	20.4	22.4	25.2
D_a kilometers	9.0	11.1	13.6	16.5	20.1

Equations 8 and 9 are utilized to determine if the first side lobe **38** is large enough at the airplane's slant range so that the airplane can maneuver, and to ensure that the first side lobes **38** of receiving antennas **32** situated across a city can "see" the airplane. The height h_{si} and width W_{sh} of the first side lobe are illustrated in FIG. 7. The height h_{si} and width W_{sh} of the first side lobe at a distance d_{sa} are given by:

$$h_{si}=d_s*\tan(\delta) \qquad \text{Equation 8}$$

$$w_{si}=2*\sqrt{(2h_{si}*d_{sa}-h_{si}^2)} \qquad \text{Equation 9}$$

The values for h_{si} and w_{si} are shown in Table Three:

TABLE Three

h_{si} kilometers	0.9	1.0	1.1	1.2	1.3
w_{si} kilometers	11.3	12.1	13.0	14.3	16.1

FIGS. 8A and 8B illustrate the geometry of the projection of the receiving antenna side lobe **38** at the position of the airplane **20**. The length and width of the area "seen" by the first sidelobe at the airplane's altitude must be calculated to determine whether the airplane **20** can stay within the sidelobe **38**. The length ⌣ of the projection of the sidelobe on the plane of the airplane's altitude is:

$$⌣=(h_d/\sin(\theta+\beta-(\delta/2)))-(h_d/\sin(\theta+\beta+(\delta/2))) \qquad \text{Equation 10}$$

and the width is:

$$W=w_{si}*h_d/\sin(\theta+\beta-(\delta/2))/d_{si} \qquad \text{Equation 11}$$

Equations 10 and 11 may be used to generate the values contained in Table Four:

TABLE Four

£ kilometers	0.5	0.7	1.0	1.3	1.7
W kilometers	15.5	17.8	21.1	26.0	34.3

If the city being served has a radius of R_c, the first sidelobes of subscribers at the edges of the city will be displaced from the center of the average volume "seen" by all sidelobes by the amount of their distance from the center of the city. The slight difference in pointing angle toward the very distant geosynchronous satellite **11** is negligible (a maximum of 0.0066 degrees at the altitudes considered here). This will constrain the airplane **20** to fly a rather tight racetrack pattern **40** to stay in the optimum serving area. The best position for the airplane **20** is as high as possible, and if the city is not circular but linear in shape (as is the case for many cities, especially coastal cities), the long axis of the racetrack pattern **40** should be on a line perpendicular to the long axis of the city. The turning radius of an airplane is determined by its speed and its angle of bank. A maximum angle of bank is about 60 degrees; this is a "two-gravity" turn, which results in a 360 degree turn in one minute. The speed of the airplane is ideally its maximum-endurance speed, about 1.2 times its stalling speed. Stalling speed, in turn, varies with weight, and decreases as fuel is burned. Stalling speed also varies considerably with the density of the air, which is a function of altitude and temperature.

The temperature in the stratosphere is relatively constant at –55 degrees Celsius. A "Standard Atmosphere" temperature of T_a=217 degrees Kelvin and a sea-level stalling speed

V_s of 50 knots (92.6 km/hr) are employed to determine the turning radius. Because of Government Air Traffic Control regulations, the airplane will fly at a constant pressure altitude regardless of its geometric altitude; the density altitude is thus a function only of temperature. The Standard Atmosphere uses a seal-level temperature of 15 degrees Celsius. Other values that are utilized to calculate the turning radius are presented in Table Five.

TABLE Five

Rate of turn, degrees/second	T_R =	6 degrees/second
Air temperature at h_a, degrees Kelvin	T_a =	217 degrees Kelvin
Sea-level stalling speed in cruising configuration	V_s =	50 knots
Density altitude = h_d = h_a * Ta/288.15;	h_d =	37654 feet
Sea level loitering speed is 1.2 * V_s	V_L =	60.0 knots
Aircraft recovery coefficient is assumed to be 0.8	C_T =	0.8

The true airspeed (TAS) is calculated in steps, as follows:

$$\text{Pressure ratio}=R_p=(((518.67-3.566*10^{-3}*h_a)/518.56))^{5.2563}$$

$$R_p=0.109248$$

$$\text{Mach number}=M=\{(5*((1/R_p)*((1+0.2(V_L/661.5)^2)^{3.5}-1)+1)^{0.2857}-1)\}^{1/2}$$

$$M=0.272168$$

$$V_{Lha}=38.96*M*\sqrt{(T_a*(C_T((1/(1+0.2*M^2))-1)+1))}$$

$$V_{Lha}=155.3$$

The turning radius is, therefore:

$$(V_{Lha}*180/T_R)/(2*60*60*\pi)=R_T=0.21 \text{ Nmi., or } 0.38 \text{ kilometers}$$

which is adequate for the objectives of the preferred embodiment, since it is within the service volume specified above.

Satellites Utilized in the Preferred Embodiment

FIG. **9A** is a schematic illustration of a geosynchronous satellite **11** that may be used to implement the present invention. The satellite includes a transponder **14** and antennas **16D** and **16U**.

FIG. **9B** offers a schematic block diagram of a satellite-borne television transponder **14**. Solar arrays **42** generate electrical power which is fed to power conditioning equipment **44**. A terrestrial uplink transmitter **46** feeds video programming **48** to a satellite uplink antenna **16U** via uplink transmitter beams **50**. Signals from the uplink antenna **16U** are processed by a band-pass filter **52**, a low noise amplifier **54** and a mixer **56** which is also connected to a local oscillator **58**. A second band-pass filter **60** conveys signals from the mixer **56** to a power amplifier **62** and then to a downlink antenna **16D**. Satellite beams **18** are collected by receiving antenna **32** and are then processed by receiver **30** and converter **64** before they are finally passed to a television TV.

Aircraft Utilized in the Preferred Embodiment

FIG. **10A** presents a schematic view of an aircraft **20** that may be used to practice the preferred embodiment of the present invention. The airplane **20** includes a transponder **22** and uplink and downlink antennas **24U** and **24D** that relay

signals from a local ground transmitter L to home receiving antennas **32**. The details of the aircraft-borne transponder **22** are revealed in FIG. **10B**. Local video programming **66** is relayed to an aircraft uplink antenna **24U** via a local uplink transmitter L which emits uplink transmitter beams **68**. A generator **70**, which may be driven by the aircraft's engine, furnishes electrical power to power conditioning equipment **72** aboard the airplane **20**. Signals from the uplink antenna **24U** are delivered to a band-pass filter **74**, a low noise amplifier **76** and a mixer **78** that is linked to a local oscillator **80**. The output of the mixer **78** is fed to a second band-pass filter **82** and a power amplifier **84** which, in turn, forwards signals to an airborne downlink antenna **24D**. Beams **26** from the airplane **20** are sensed by receiving antenna **32**, which is coupled to receiver **30**, converter **64** and television TV.

FIG. **11** shows the airplane **20** flying in a generally closed loop pattern **40**. Although the preferred embodiment of the invention is implemented using a manned airplane, alternative embodiments of the invention may be practiced using a blimp, a dirigible, a helicopter, both free and untethered balloons, aerostats or any other airborne platform that will serve as a reliable source for providing signals to receiver antennas **32**.

Home Receiving Antennas

FIG. **12** illustrates a receiving antenna **32** mounted on the rooftop of a home H. A terminal **28** includes a direct broadcast receiver **30** connected to the antenna **32**, a converter **64** and a television TV. FIG. **13** offers a perspective view of a receiving antenna **32**.

Various methods may be employed to deliberately enhance the gain of the side lobe **38** of the receiving antenna **32**. In a conventional paraboloidal reflector, the antenna surface **35** is carefully contoured to approximate shape of a true paraboloid to maximize the gain of the main lobe **36**. In one embodiment of the invention, the antenna surface **35** may be deliberately distorted to augment the gain of the side lobe **38**. Another technique which strengthens the sensitivity of the side lobe **38** is to decrease the taper of the radiation emitted by the feedhorn structure **37** so that it illuminates the edges of the reflector **32** more strongly. Another alternative that exaggerates the action of the side lobe **38** is to reduce the size of the receiver antenna **32**, or to reduce the radius of the antenna **32** in the direction in which the side lobe **38** is to be enhanced. The side lobe **38** may also be effectively boosted by distorting the shape of the energy radiated from the feedhorn structure **37** so that the reflector **32** is illuminated more strongly in an off-axis direction.

Yet another method of improving side lobe **38** sensitivity is to move the feedhorn structure **37** slightly closer to the reflector relative to its normal position. This alteration defocuses the beam slightly, and makes the first side lobe **38** stronger and the main lobe **36** very slightly weaker. Another alternative method involves forming a small dimple in the feedhorn structure **37** or a by making a small dent in the reflector **32**.

The present invention may also be implemented using a receiving antenna **32** which is specially built to have an adjustable shaped beam that is specifically suited to detect signals from the airplane **20**.

The present invention exploits an inherent weakness in receiving antennas, and also exploits the fact that antennas manufactured at the time this Patent Application is being filed which are used to receive broadcasts from geosynchro-

nous broadcast satellites using newly-occupied K_u-band (about 14 GHz) are of identical design.

CONCLUSION

Although the present invention has been described in detail with reference to particular preferred and alternative embodiments, persons possessing ordinary skill in the art to which this invention pertains will appreciate that various modifications and enhancements may be made without departing from the spirit and scope of the claims that follow. The various orbital parameters, satellites, aircraft and receiving antennas that have been disclosed above are intended to educate the reader about particular embodiments, and are not intended to constrain the limits of the invention or the scope of the claims. The *List of Reference Characters* which follows is intended to provide the reader with a convenient means of identifying elements of the invention in the specification and drawings. This list is not intended to delineate or narrow the scope of the claims.

LIST OF REFERENCE CHARACTERS	
10	Schematic diagram of geosynchronous satellites in Earth orbit
11	Satellites
12	Earth orbit
13	Schematic diagram showing direct satellite broadcast to home
14	Satellite transponder
16D	Satellite downlink antenna
16U	Satellite uplink antenna
18	Satellite beams of radiation
20	Airborne platform
22	Airborne platform transponder
24D	Airborne platform downlink antenna
24U	Airborne platform uplink antenna
26	Airborne platform beams of radiation
28	Terminal
30	Receiver
32	Receiver antenna
33	Schematic diagram showing preferred embodiment of present invention
34	Central axis of antenna
35	Surface of receiver antenna
36	Main antenna lobe
37	Feedhorn structure
38	Side antenna lobe
40	Flight path
42	Solar array
44	Power conditioning equipment
46	Uplink transmitter
48	Video programming
50	Uplink transmitter beams
52	Band-pass filter
54	Low noise amplifier
56	Mixer
58	Local oscillator
60	Band-pass filter
62	Power amplifier
64	Converter
66	Local video programming
68	Local uplink transmitter beams
70	Engine-driven generator
72	Power conditioning equipment
74	Band-pass filter
76	Low noise amplifier
78	Mixer
80	Local oscillator
82	Band-pass filter
84	Power amplifier
E	Earth
F	Footprint
H	Home
L	Local ground television transmitter

What is claimed is:

1. A communications apparatus comprising:

a satellite (11) in Earth orbit (12); said satellite (11) including a satellite transponder (14) and a satellite antenna (16) for conveying a set of satellite beams of radiation (18) toward the surface of the Earth (E);

an airborne platform (20); said airborne platform (20) including an airborne platform transponder (22) and an airborne platform antenna (24D, 24U) for conveying a set of airborne platform beams of radiation (26) toward the surface of the Earth (E); and

a terminal (28); said terminal (28) including a receiver (30) and a receiver antenna (32);

said receiver antenna (32) having a central axis (34) and a main antenna lobe (36); said main antenna lobe (36) being generally coaxial with said central axis (34); said main antenna lobe (36) being pointed toward said satellite (11) and being used to receive said set of satellite beams of radiation (18);

said receiver antenna (32) also having an antenna surface (35) and a feed structure (37);

said receiver antenna (32) further having a side antenna lobe (38); said side antenna lobe (38) being generally coaxial to said central axis (34); said side antenna lobe (38) being used to receive said set of airborne platform beams of radiation (26);

said airborne platform (20) being flown along a flight path (40) which permits said airborne platform (20) to transmit said set of airborne platform beams of radiation (26) to said receiver antenna (32) using said side antenna lobe (38) while said central axis (34) of said receiver antenna (32) is pointed toward said satellite (11).

2. An apparatus as claimed in claim 1, in which said airborne platform (20) operates at high altitudes.

3. An apparatus as claimed in claim 1, in which said airborne platform (20) operates at an altitude of approximately 50,000 feet.

4. An apparatus as claimed in claim 1, in which said airborne platform (20) operates at an altitude of from 50,000 to 80,000 feet.

5. An apparatus as claimed in claim 1, in which said airborne platform (20) operates in a generally closed loop pattern (40).

6. An apparatus as claimed in claim 1, in which said surface (35) of said receiver antenna (32) is deliberately distorted to augment the gain of said side lobe (38).

7. An apparatus as claimed in claim 1, in which the taper of the radiation emanating from said feed structure (37) is decreased so that the edges of said receiver antenna (32) are illuminated more strongly and the gain of said side lobe (38) is augmented.

8. An apparatus as claimed in claim 1, in, which the gain of said side lobe (38) is increased by reducing the size of said receiver antenna (32).

9. An apparatus as claimed in claim 1, in which the gain of said side lobe (38) is enhanced by reducing the radius of said receiver antenna (32) in the direction in which said side lobe (38) is to be enhanced.

10. An apparatus as claimed in claim 1, in which said side lobe (38) is boosted by distorting the shape of the energy radiated from the feed structure so that said receiver antenna (32) is illuminated more strongly in an off-axis direction.

11. An apparatus as claimed in claim 1, in which said side lobe (38) is enhanced by moving said feed structure (37) slightly closer to said receiver antenna (32).

12. An apparatus as claimed in claim 1, in which said side lobe (38) is strengthened by forming a small dimple in said feed structure (37).

13. An apparatus as claimed in claim 1, in which said side lobe (38) is strengthened by making a small dent in said receiver antenna (32).

14. An apparatus as claimed in claim 1, in which said receiving antenna (32) is specially built to have an adjustable shaped beam that is specifically suited to detect signals from said airborne platform (20).

15. An apparatus as claimed in claim 1, in which said airborne platform (20) is an airplane.

16. An apparatus as claimed in claim 1, in which said airborne platform (20) a blimp.

17. An apparatus as claimed in claim 1, in which said airborne platform (20) is a dirigible.

18. An apparatus as claimed in claim 1, in which said airborne platform (20) is a helicopter.

19. An apparatus as claimed in claim 1, in which said airborne platform (20) is a balloon.

20. An apparatus as claimed in claim 1, in which said airborne platform (20) is an aerostat.

21. A method of augmenting a satellite broadcast system comprising the steps of:

operating a receiving antenna (32); said receiving antenna (32) having a main lobe (36) and a side lobe (38);

sensing a set of satellite beams of radiation (18) transmitted from a satellite (11) in Earth orbit (12) using said main lobe (36) of said receiving antenna (32);

operating an airborne platform (20) over the surface of the Earth; said airborne platform (20) including an airborne platform transponder (22) and an airborne platform antenna (24D and 24U);

conveying a set of airborne platform beams of radiation (26) toward the surface of the Earth (E) to said receiving antenna (32); and

simultaneously sensing said set of airborne platform beams of radiation (26) using said side lobe (38) of said receiving antenna (32).

*   *   *   *   *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO.　:　**5,584,047**

DATED　　　:　December 10, 1997

INVENTOR(S) :　Edward F. Tuck

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

Column 5, line 34:　"an" should be ---at--.

Column 5, line 44:　delete "**42**".

Column 7, line 29:　"⊔" should be --£--.

Column 7, line 31:　"⊔" should be --£--.

Column 8, line 6:　"seal-" should be --sea-.

Column 9, line 58:　delete "a" after --or--.

Signed and Sealed this

Nineteenth Day of August, 1997

Attest:

BRUCE LEHMAN

Attesting Officer　　　　*Commissioner of Patents and Trademarks*