Nov. 17, 1970 S. GUBIN 3,541,553

SATELLITE COMMUNICATIONS SYSTEMS

Original Filed April 26, 1967 5 Sheets-Sheet 1

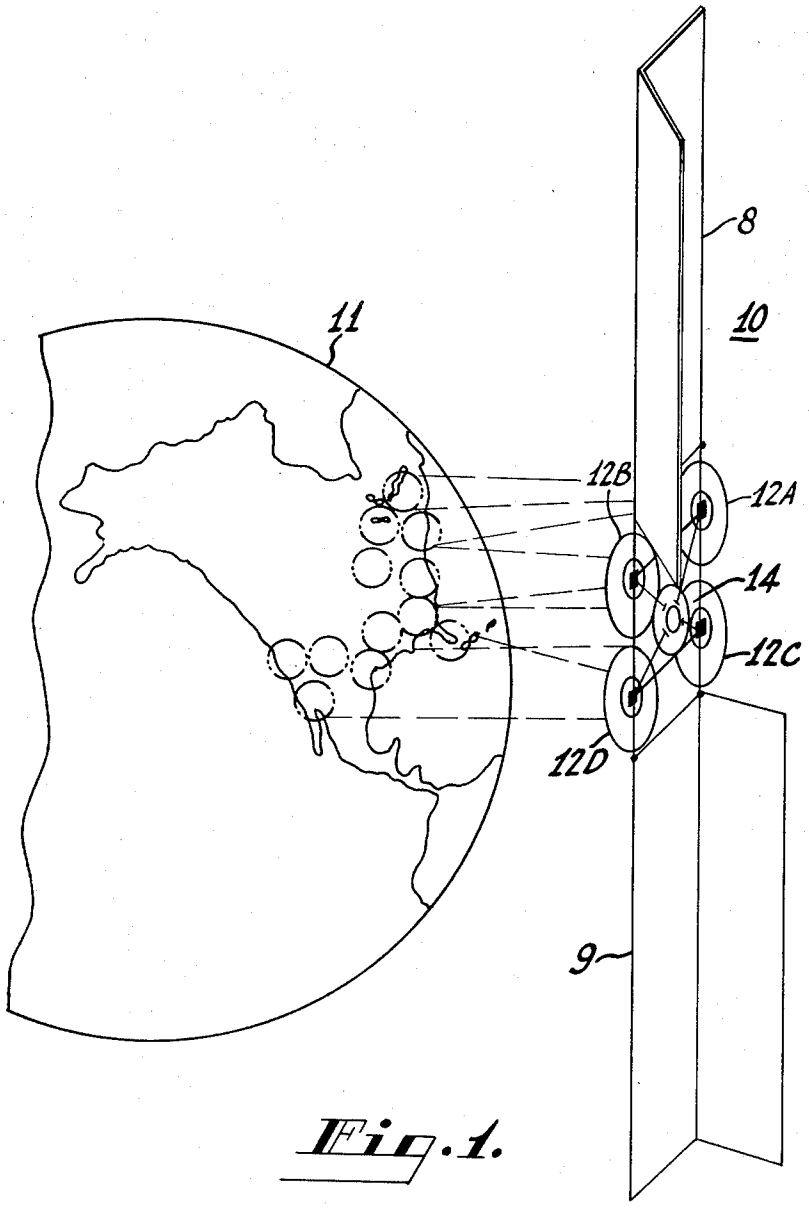


Fig. 1.

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SATELLITE COMMUNICATIONS SYSTEMS

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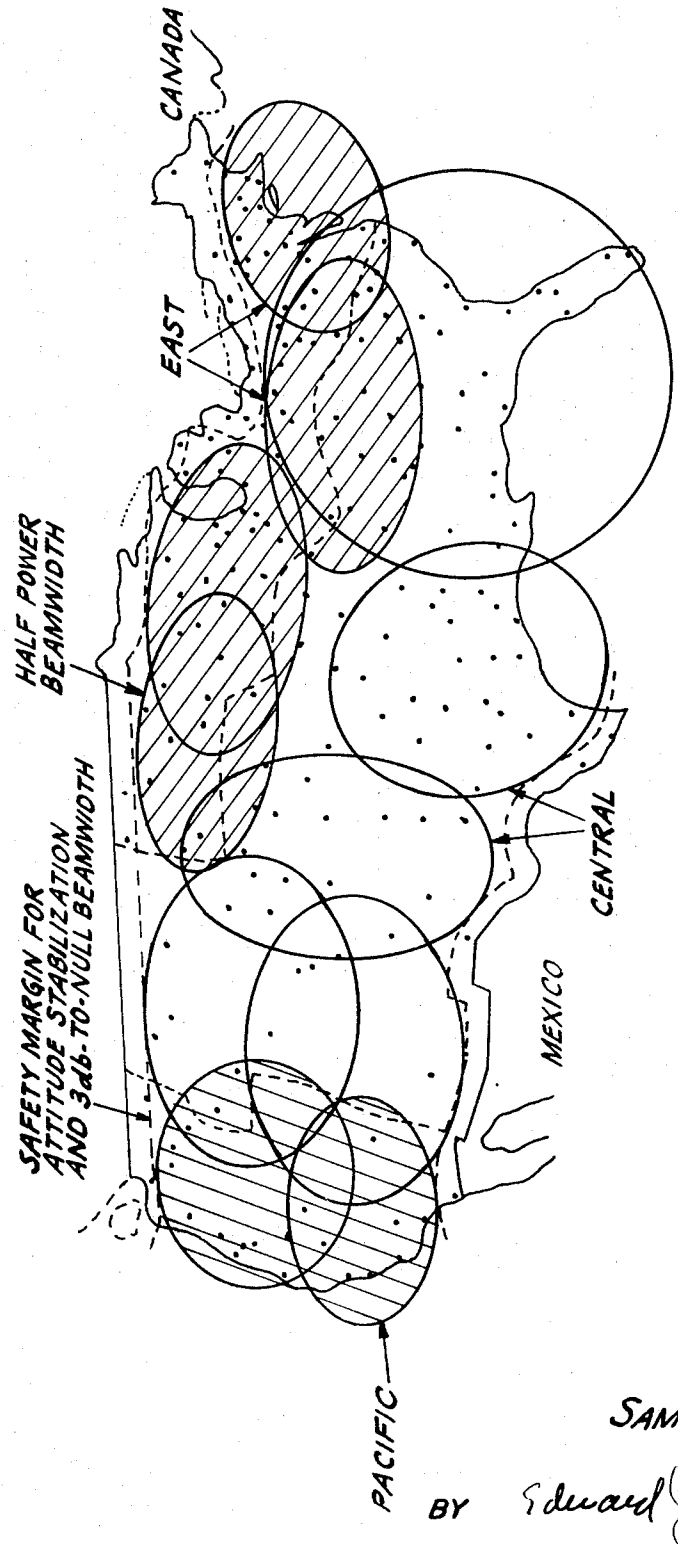


Fig. 2.

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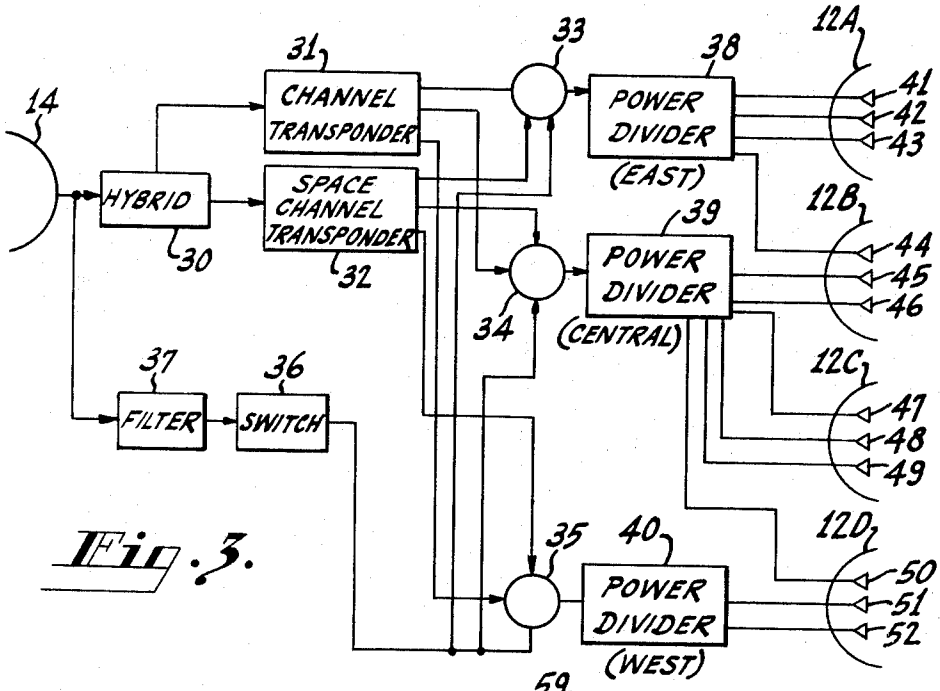


Fig. 3.

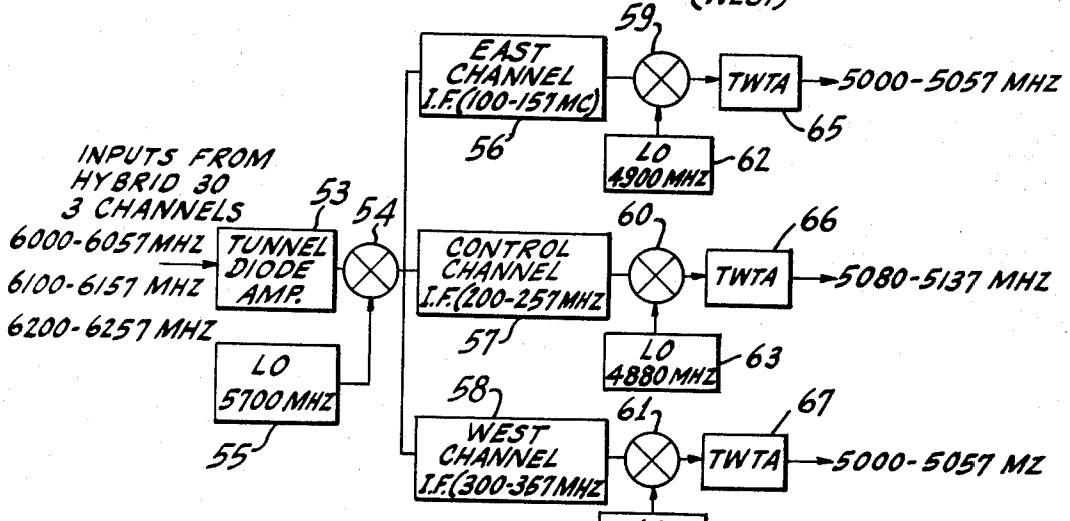


Fig. 4.

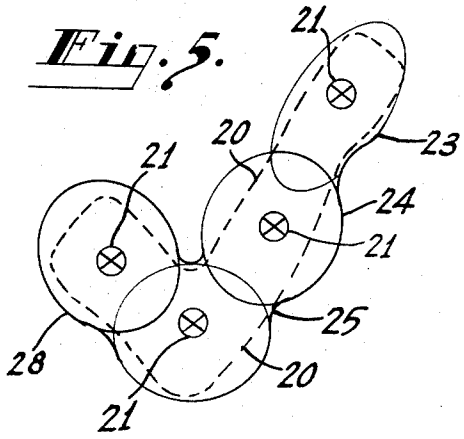
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SATELLITE COMMUNICATIONS SYSTEMS

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Fig. 5.



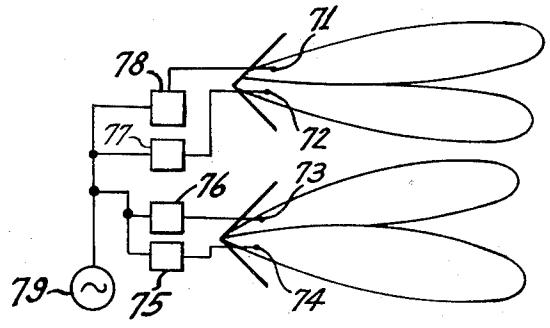


Fig. 6.

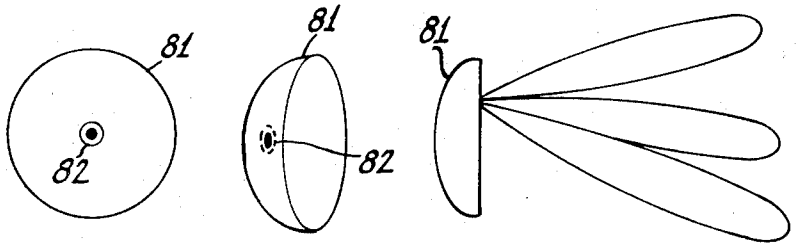


Fig. 7A. Fig. 7B. Fig. 7C.

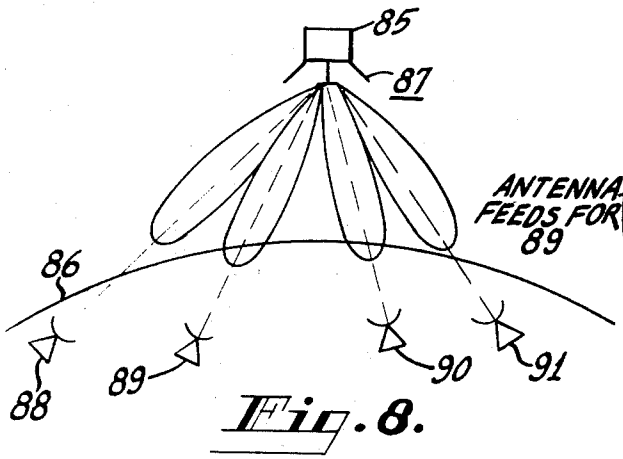


Fig. 8.

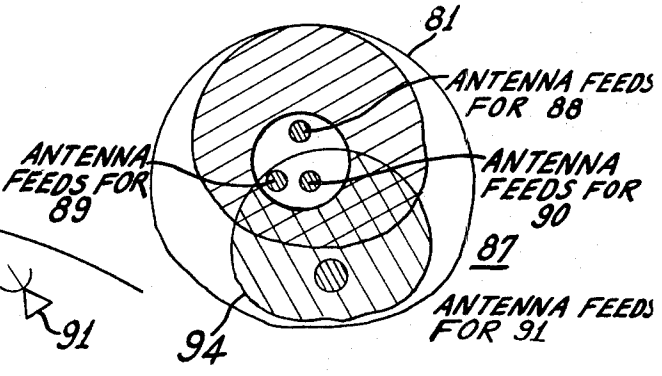


Fig. 9.

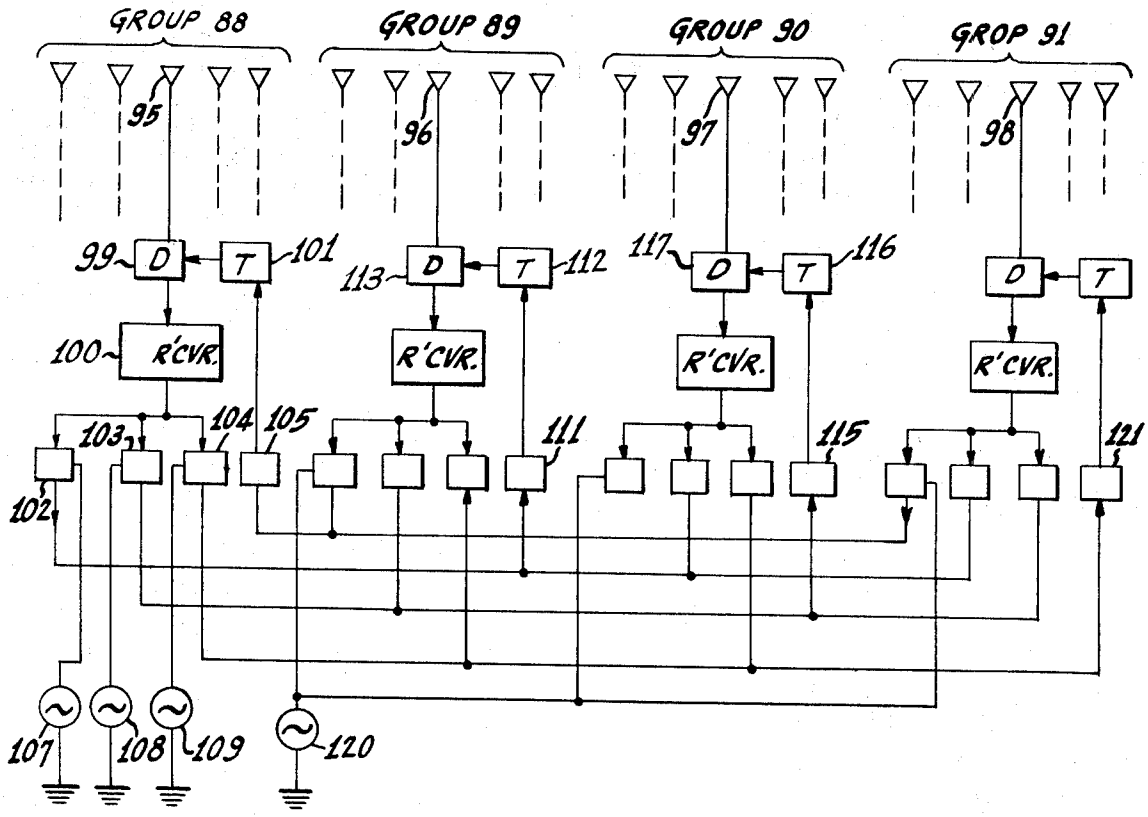
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SATELLITE COMMUNICATIONS SYSTEMS

Original Filed April 26, 1967 5 Sheets-Sheet 5

Fig. 10.



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United States Patent Office 3,541,553 Patented Nov. 17, 1970

3,541,553

SATELLITE COMMUNICATIONS SYSTEMS

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Continuation of application Ser. No. 633,908, Apr. 26, 1967. This application Mar. 27, 1968, Ser. No. 716,668
Int. Cl. H04b 13/00
U.S. Cl. 343—100 4 Claims

ABSTRACT OF THE DISCLOSURE

A communication system employing a satellite capable of providing full communication coverage of an irregularly shaped area on the surface of the earth or some other celestial body is described, it being desired to confine radiation only within or substantially within the irregularly shaped area. A satellite is placed in orbit about the body and in view of the desired area. The satellite is preferably placed in a synchronous orbit whereby it will appear to hover in one spot in relation to that area irrespective of the movement of the celestial body but the concept may also be applied to an orbiting satellite. The satellite has associated with it a plurality of antenna elements, each of which or a group of which are designed to transmit a radiation pattern that covers an elementary area of the irregularly shaped area in the manner of a mosaic. An irregularly shaped area can be divided into a number of elementary areas which together comprise the total. Each of the antenna elements or groups of them are then designed to cover one of these smaller areas. There are means aboard the satellite responsive to radiated signals from the earth's surface to cause the plurality of antenna elements to radiate to the surface by forming a composite beam whose radiation pattern substantially conforms to the irregularly shaped area thereby providing full communication coverage.

This application is a continuation of application Ser. No. 633,908, filed Apr. 26, 1967, now abandoned.

There is little doubt that future communication systems will include systems employing satellites for providing communication coverage to various locations on the earth. Such satellite systems will be used for commercial, educational or military transmissions of television and aural program material or for 2-way voice communications, data and other (information) transmissions. All frequency bands in which satellite links will operate efficiently because of favorable propagation have not been allocated for global use. For example, the 5,000 to 5,250 mHz. frequency band is a radio-navigation allocation not used in the U.S.A. This band is a desired satellite operating band, but because there is no international agreement permitting its use in satellite communications, such a system would have to confine its radiation to the continental U.S.A. Even so, this frequency band could be allocated to television networking, for example, if such action was in the national interest. The geographical constraint on the radiation requires that the satellite to be operated in this band develop a radiation pattern which would practically fit the boundaries of the United States. The same limitations may exist for transmission to other areas. In any case it would be highly desirable to confine a radiation pattern within a desired area to prevent or minimize interference with communication systems that might be operating with the same frequencies in other geographical locations. The prior art in satellite communication systems uses satellites having antennas at low directivity whose radiation patterns spread over continental or hemispherical areas.

It is therefore an object of the present invention to provide an improved communication system employing a satellite capable of confining its transmitted energy within a specified irregular area.

Another object is to provide a satellite communication system utilizing a frequency which is not allocated for global use by causing the satellite to confine its radiation to a specified area.

These and other objects of the present invention are accomplished by placing a satellite in a stationary orbit in full view of an irregularly shaped area. The satellite has a plurality of antenna elements wherein each element or a group of such elements is capable of transmitting a radiation pattern whose cross-sectional area corresponds to elemental areas of the irregularly shaped area. The irregularly shaped area may be defined by a plurality of smaller areas containing transmitting stations or beacons. The antenna elements associated with the satellite are caused to respond to the transmissions from these beacons so that each antenna element or group of elements directs a beam in accordance with the transmitted beacon signal to cause the plurality of antenna elements to form a composite beam whose cross sectional area is substantially equal to that of the irregularly shaped area. Alternatively, in the absence of a network of beacons, the beam directions may be preset before launch requiring only the control of the satellite altitude, a known art or the beams may be steered using ground command signals.

These and other objects of the present invention will become clearer if reference is made to the following specification and drawings, in which:

FIG. 1 is a pictorial view of a satellite in orbit about the earth which satellite contains transmitting equipment in accordance with this invention.

FIG. 2 is a pictorial view of the continental United States with superimposed radiation patterns in accordance with this invention.

FIG. 3 is a block diagram of a communications subsystem which can be employed aboard a satellite.

FIG. 4 is a block diagram showing a portion of FIG. 3 in greater detail.

FIG. 5 is a diagrammatic view of beacon locations within an irregular area to clarify the system operation.

FIG. 6 is a schematic view of an antenna system which could be employed with this invention.

FIGS. 7A–C are perspective views of a reflector and a feed which could be used in this invention.

FIG. 8 is a pictorial view of a satellite in relation to ground stations operating in accordance with this invention.

FIG. 9 is a pictorial view showing the geometrical relations of a reflector type antenna used with this invention.

FIG. 10 is a partial block and schematic diagram showing traffic routing to an antenna array according to this invention.

If reference is made to FIG. 1, there is shown a satellite **10** in a synchronous orbit about the earth **11**. As can be seen from the figure, the satellite **10** is in view of the North American continent. The satellite **10** includes a plurality of antenna reflectors respectively designated as **12A**, **12B**, **12C**, **12D**. Each reflector **12A** to **12D** may be fed by a multiple feed causing the combination of the four reflectors to produce a series of beams which will illuminate only the irregularly shaped area on the North American continent known as the U.S.A. A pair of panels **8** and **9** are shown for providing an isotropic solar supply.

If reference is made to FIG. 2, there is shown a map of the continental United States wherein substantially the total area is covered by a plurality of radiation beams. Each beam is formed by a discrete antenna feed element in the focal plane of a reflector mounted on the satellite

10, or by other means including the use of a plurality of antennas or a phased array. The twelve beams in the example shown in FIG. 2 can also be produced by illuminating each of three reflectors with four feeds per reflector or other combinations of numbers of reflectors and feeds. Each of the reflector feeds as will be described later can be designed so as to deliver shaped beams in combination with its respective reflector as 12A–12D. The beams which provide coverage along the boundaries of Canada and Mexico may have "beaver tail" shapes to produce a flat nose beam with rapid fall off. This facilitates the use of a guard zone which can be accurately controlled. The guard zone is necessary to prevent radiation spill over into Canada and Mexico. The areas in the United States within this guard band can be serviced by conventional land communications systems such as microwave links or cable.

FIG. 1 specifically shows the satellite 10 as having a transmitting antenna comprising four parabolic or spherical reflectors 12A, 12B, 12C, 12D each specifically having three feeds to produce the total of twelve beams as shown in FIG. 2 necessary to cover the continental United States. The earth area illuminated by each of the beams varies in shape and hence radiation in each beam varies in intensity. FIG. 2 shows the Eastern time zone being covered by four beams, the Central time zone covered by six beams, and the Western time zone by two beams. The elliptic shape of some of the beams may be produced by an extended antenna feed properly oriented with respect to the spacecraft's axes.

If reference is made to FIG. 3, there is shown a communications subsystem which may be employed aboard satellite 10 of FIG. 1 to feed the four parabolic reflectors 12A–D and to produce the twelve beam radiation pattern coverage shown in FIG. 2. This subsystem permits the transmission of three program channels, one per time zone of the geographical area covered by the twelve beam antennas.

Numeral 14 references a receiving antenna which may be the center antenna 14 shown in FIG. 1 abroad satellite 10. Assume a ground beacon transmits to the satellite 10 in a 257 mHz. portion of the shared 5.925–6.425 mHz. band. Antenna 14 receives the signals within this frequency band. The information received may contain television signals and may represent one network with 3 channels or 4 networks with 6 channels. In any case, the signal received by antenna 14 is coupled to a hybrid divider 30 which is used to couple the received power to a transponder 31 and a spare unit 32. The function of the transponders 31 and 32 is to receive the up-link signals and to translate these to the down-link frequency in the 5 gHz. band for the East, Central and Western time zone of the U.S. In addition the transponder amplifies the received signal to a level suitable for retransmission. The exact nature and function of the transponders 31 and 32 will be described in greater detail in conjunction with FIG. 4. The hybrid 30 may be of the type shown in Hybrid Circuits for Microwaves by W. A. Tyrell, Proc. IRE, vol. 35, page 1294, November 1947. The output of the transponder 31 and of the spare unit 32 are fed into circulators 33, 34 and 35. The circulators are of the switching type and allow the use of the spare transponder 32 in case of failure of transponder 31. Circulator switches as 33–35 are known in the art and examples of operation and configuration of such units can be found in Operation of the Ferrite Junction Circulator by C. E. Fay and R. L. Comstock, IEEE Transactions of Microwave Theory and Techniques, January 1965, pages 15–27.

The circulators 33–34 have their switching element, which may be a ferrite bar, coupled to a switch 36 whose input is coupled to a filter 37. The input of the filter 37 is coupled to the receiving antenna 14. Hence the ground station may transmit a discrete frequency switching tone which frequency is passed by the filter 37 to cause actuation of the switch 36, changing the direction of the magnetic bias on the circulators and causing the power from the redundant transponder 32 to be coupled to the output of the circulators 33–35 in case of the failure of transponder 31.

The outputs of the circulators 33–35 are respectively coupled to feeds or antenna elements via power dividers 38–40. The feeds produce the beams to illuminate the desired portion of the irregular shaped area, which in this case would be the United States. The power dividers 38, 39 and 40 provide distribution of the transponder 31 or 32 power output to each respective feed in accordance with the feed's position within the parabolic reflectors 12A to 12D and its predetermined share of the satellite radiated power. Hence to accommodate the Eastern section of the U.S.A. there are needed, as shown in FIG. 2, four beams. The beams are produced by the position of the antenna elements or feeds 41, 42, 43 located within reflector 12A, and the fourth beam is produced by the positioning of antenna element 44 within reflector 12B. The power divider 38 then distributes power to each of the elements 41, 42, 43, 44 according to their position within their respective reflectors 12A and 12B, while further performing impedance matching. The reflectors may be pointed to the center of their coverage area; 12A's axis would be in the direction of the Eastern part of the U.S.A. as an example. Such devices for accomplishing this are known in the art and not considered part of this invention. In a similar manner power divider 39 feeds elements 45 through 50 to provide the six beam coverage needed for the Central portion of the U.S.A. The Western portion is accommodated by power divider 40 feeding antenna elements 51 and 52 located within reflector 12D.

If reference is made to FIG. 4, there is shown a typical transponder which may be used for the blocks indicated in FIG. 3 as 31 and 32, which is a three channel transponder for accommodation of one television network. The input from hybrid 30 is the frequency bands representing three channels. The first channel being 6,000 to 6,057 mHz., the second channel being 6,100 to 6,157 mHz., and the third channel being 6,200 to 6,257 mHz. A tunnel diode amplifier 53 is a negative resistance amplifier capable of low noise operation and serves to amplify the signals from the hybrid 30 to a level compatible with the dynamic range of mixer 54 whose input is coupled to the output of the tunnel diode amplifier 53. For an example of such an amplifier 53, see U.S. Pat. No. 3,127,567 entitled Negative Conductance Diode Amplifier by K. K. N. Chang. The output of the tunnel diode amplifier 53 is coupled to one input of the mixer 54, which may be a varactor or crystal diode mixer circuit or a hybrid mixer. The other input to mixer 54 is derived from an oscillator circuit 55 which in this case produces a signal at 5,900 mHz. The mixer 54 is operated as a down convertor so that the lower sideband signal which is the difference in frequency between the 5,900 mHz. oscillator 55 and the output from the tunnel diode amplifier 53 is taken. It can also be seen that in lieu of the tunnel diode amplifier 53 and mixer 54 an amplifying down convertor such as a parametric device can be used to obtain both low noise operation and down conversion from one device. The output of mixer 54 is coupled to the inputs of three relatively narrow band intermediate frequency amplifiers 56, 57, 58 which serve to amplify the East, Central, and West channel signals. The output of each respective I.F. amplifier 56, 57, 58 is coupled to an associated mixer circuit 59, 60, 61. The function of these mixer circuits is to take the respective I.F. signals for the East, Central and West channels and produce a signal to be transmitted from the satellite's antenna elements as 41 through 52 of FIG. 3. Each mixer 59, 60, 61 is also coupled to a separate oscillator 62, 63, 64 which serves to up convert the I.F. frequency into the desired frequency band to be used in providing communication coverage of an irregular area as the U.S.A. In this case the Eastern band local oscillator 62 is set at 4,900

mHz. to mix with the 100 to 157 mHz. I.F. producing an upper sideband at 5,000 to 5,057 mHz. The corresponding frequency ranges for the Central and Western channels are shown in the figure. The up-converted signals from the mixers **59**, **60**, **61** are coupled to the input of a traveling wave tube amplifier (TWTA) associated with each channel. Hence the output of mixer **59** is coupled to TWTA **65** to produce a high power signal in the 5,000 to 5,057 mHz. band. The amplified signal produced by TWTA **65** is the output from the transponder **31** or **32** shown going to circulator **33** of FIG. 3. The output of TWTA **66** is coupled to circulator **34** of FIG. 2, and TWTA **67** is coupled to circulator **35** of FIG. 3. In the manner shown in FIGS. 3 and 4 more networks and channels can be accommodated by expanding the transponder in a manner to add more I.F. amplifiers as **56** through **58** to accommodate the different bands.

FIG. 5 shows an irregularly shaped area defined by the dashed line **20**. In order to illuminate this area from a satellite such as **10** of FIG. 1 there is shown four beacons each referenced by numeral **21**. As seen from FIG. 3 the beacons are placed in strategic locations within the irregularly shaped area **20**. These beacons **21** transmit to a satellite as **10** of FIG. 1 and the satellite **10** produces a beam of a specified shape such as that shown by the ellipitical cross section **23**. The respective antenna element or elements which produce a radiation pattern as **23** would be responsive to the reception of the signal from the beacon **21** and would redirect the transmitted signal back to the beacon **21** thereby illuminating an area surrounding the beacon **21**. This area would correspond to a portion of the irregularly shaped area **20**. Hence in FIG. 5, the composite radiation pattern defining area **20** is represented by the four patterns **23** through **26** respectively. In the manner shown in FIG. 2, the U.S.A., any geographical area or any other area can be accommodated in the same manner. Hence, for the plurality of ellipitical and circular cross sectional radiation patterns shown in FIG. 2, there would be an antenna or a plurality of antenna elements in combination with reflectors aboard the satellite capable of transmitting the desired radiation pattern in response to a beacon or a transmitter such as **21** located at the irregularly shaped area which in this case could be the United States.

If reference is made to FIG. 6 there is shown one type of antenna which is capable of producing multiple beams when excited by multiple feeds or multiple antenna elements. Numeral **70** represents a reflector plate which may be bent at a suitable angle and fabricated from aluminum, electroplated foam plastic or some other suitable conducting material. Located between the two side portions of the reflector **70** are shown two antenna elements referenced as **71** and **72**. These elements **71** and **72** are each coupled to an amplifier or an impedance matching device **77** and **78**, respectively. The input terminals of the amplifiers **77** and **78** are coupled to a carrier frequency source **79**. Also shown coupled to the carrier frequency source are two more amplifier or impedance matching devices designated as **75** and **76** which devices have their outputs respectively coupled to two other antenna or feed elements designated as **73** and **74**. These are also located between the sides of a reflecting plate **80** and in conjunction with this reflecting plate are also capable of producing multiple beams. The configuration shown in FIG. 6 is described in the prior art as a corner reflector antenna and for more details of operation of such antennas reference is made to an article entitled "The Corner Reflector Antenna" by John D. Krauss, published in the Proceedings of the IRE, November, 1940, volume 28, No. 11, pages 513–519. There are many other means known to the prior art for producing multiple beams from antenna elements in combination with reflectors. It is also known in the prior art how to shape radiation patterns emanating from an antenna element in a manner so that its cross sectional area can assume an elliptical, circular or some other desired geometrical configuration. For further detail on how one may obtain such radiation patterns or multiple beam generation reference is made to "Antennas" by John D. Krauss, published by McGraw Hill Book Company, 1950.

If reference is made to FIGS. 7A through 7C there is shown a further antenna configuration which can also be used for multiple beam generation while possessing the further property of being able to automatically redirect a received signal back in the direction from where it was transmitted or in a direction determined by the direction of transmission. The antenna comprises a reflector **81** and a primary feed **82**. The reflector **81** may be parabolic or spherical in shape or, in fact, may have other geometrical shaping. The primary feed **82** is a retrodirective phase array which is located near the focus of the reflector **81** such that the energy reflected by the reflector **81** is distributed in amplitude and phase over the aperture of the primary antenna. In the use of the antenna it is desired that the primary reflector **81** retransmit in conjugate phase the signal received from a beacon or transmitter located on the ground. The spacial distribution transmitted amplitude is proportional to that received but the transmission is at a slightly different frequency than that received. If this is so then the conditions for transmitting a beam back in the same direction as the beacon signal received are met. This latter principle is described in U.S. Pat. 2,908,202 by L. C. Van Atta, issued Oct. 6, 1959. The Van Atta Array is a passive device in contrast to the active conjugate phase array principle used in this disclosure. The specific details for accomplishing this will be further described in conjunction with the description of the remaining figures. However, the advantages of such an antenna as shown in FIGS. 7A, 7B and 7C are many. Among the advantages are an antenna configuration of considerable mechanical simplicity, capable, for example, of being deployed on a satellite. Such an antenna is capable of providing several beams simultaneously, each independently steered by an external beacon signal source, thus, eliminating mechanical devices while further providing the capability of scanning each beam over a wide pointing angle. The amplitude and phase correction provided by the phased array feed compensates for mechanical tolerances resulting from the construction or deployment of the antenna, thus offering the possibility of using large antennas. As will be seen later, the antenna provides for graceful degradation in performance as elements fail. It is adapted to solid state circuitry and serves to reduce the required number of phased array elements normally required for a given beam width.

If reference is made to FIG. 8, there is shown a satellite **85** in a stationary orbit with respect to a celestial body **86** which may be the earth. The satellite **86** has an antenna **87** mounted thereon which antenna **87** is that shown in FIGS. 7A through 7C, namely, a reflector containing a retrodirective array as a primary feed. Also shown are ground stations **88**, **89**, **90**, **91** located at strategic points on the surface of the body **86** and in full view of the satellite **85**. The satellite **85** is in communication with the ground stations **88** through **91** in the following manner. Ground station **88** transmits to the satelite **85** on a specified up link frequency f_0. This signal transmitted from station **88** contains the traffic information for stations **89**, **90** and **91** and for the area in the vicinity thereof. Similarly station **89** transmits information to stations **88**, **90** and **91** via the satellite **85** on the same up link frequency f_0. In the satellite **85**, the down link transmission to the ground stations **88** through **91** is broadcast on a frequency f_d. In this manner each ground station **88** through **91** uses the same up-link frequency f_0 and the same down-link frequency f_d.

If reference is made to FIG. 9, there is shown a front view of the antenna **87** of satellite **85**. The signal from ground station **91** is caused to illuminate an area of the

reflector **81** of antenna **87** which corresponds to the satellite beams for ground stations **88**, **89** and **90**. The satellite antenna feeds for transmission to stations **88**, **89** and **90** are retrodirective arrays and by their nature will cause a beam to be directed towards these respective ground stations. If it is desired to direct a signal to ground stations **89**, **90** and **91**, the area on the reflector **81** referenced as **94** would be illuminated by station **88** in the manner shown in FIG. 9. The active areas of reflector **81** to be illuminated are selected prior to launch because the ground station's **88** through **91** locations and the satellite **85**'s sub-orbital point are all known.

If reference is made to FIG. 10, one embodiment of the routing equipment aboard the satellite is shown. Each ground station of FIG. 8, or any number of ground stations, has a plurality of elements associated with the satellite assigned thereto, which elements form a retrodirective array and will cause a beam to be pointed at that ground station, providing a received beam in the proper direction illuminates the area of the reflector **81** of FIG. 9 which contains these elements. Hence in FIG. 10 there is shown a plurality of antenna elements split up into four groups designated as groups **88** through **91** each corresponding to the respective ground station of FIG. 8. The elements associated with each group **88** through **91** are arranged as a retrodirective array within a reflector **81** aboard the satellite. For the sake of simplicity one antenna element in each group is shown coupled to the asscoiated circuitry to show how a typical signal is routed. It is understood that each element in a group **88** through **91** has similar circuitry associated with it.

Antenna element **95** is an element in the retrodirective array associated with ground station **88** and referenced as group **88** in FIG. 10. Element **95** may be any radiating member such as a dipole, helical, or turnstile antenna, capable by itself of producing a fairly narrow radiation beam. The element **95** is coupled to one terminal of a diplexer **99**. The function of the diplexer **99** is to allow the antenna element **95** to be used simultaneously at both the transmitting and receiving frequencies while providing isolation between the receiver and transmitter. Many types of diplexers are suitable for use in block **99**, for example, see "Microwave Circuits" by J. L. Altman, D. Van Norstrand Co., Inc. (1964) pages 351–358. An arm of the diplexer **99** is coupled to a receiver **100**, which receiver is capable of responding to the frequency band transmitted by a ground station. The output of the receiver **100** is filtered to provide separate outputs for the information signals to be transmitted to ground stations **89** through **91** of FIG. 9 via their associated array elements. Hence the receiver **100** is coupled to filters or mixer circuits **102** to **104**, there being a separate one for each group. For example, filter **102** is coupled to block **111** associated with group **89**. Block **111** is an exciter circuit which filters and amplifies the signal to be transmitted by the group **89** array. The output of exciter **111** is coupled to the input of a transmitting amplifier **112** that is coupled to an arm of the diplexer **113** associated with group **89**. In a similar manner, the antenna element **96** associated with group **89** can be used for both transmission and reception of signals, as can any other antenna element in said group or any other group.

As an example of the operation of the system shown in FIG. 10, assume a portion of the satellite's reflector is illuminated by a beacon such that the satellite antenna elements of group **88** receive a signal. Element **95** will pick up a signal which represents a portion of the wavefront of the transmitted signal. The diplexer **99** then causes this signal to be coupled to receiver **100** which amplifies it and splits the power to mixers and matching devices **102** through **104**. Devices **102** through **104** have coupled thereto respective oscillators **107** through **109** provide signals for transmission back to earth at a frequency equal to the sum or difference of the output of the receiver **100** and the respective oscillators **107** through **109**. Hence, there is a signal provided via devices **102** through **104** for each of the groups **89**, **90**, **91** for transmission back to earth by the array associated with the group. As stated before, device **102** is coupled to exciter **111** of group **89** which amplifies and filters the signal. The output of exciter **111** is coupled to a transmitting amplifier **112** which feeds the signal to the diplexer **113** which in turn causes the signal to be coupled to the antenna element **96** which transmits the signal to ground station **89**. In a similar manner, device **103** is coupled to exciter **115** which is associated with group **90** and in the manner described excites transmitting amplifier **116** whose output is coupled to antenna element **97** associated with group **90** via diplexer **117** to transmission to ground station **90**. It can be seen that the reception of a signal by elements **96** through **98** associated with groups **89** through **91** will cause a signal to be sent to exciter **105** associated with group **88**. The signal is coupled via the exciter **105**, the transmitting amplifier **101**, and the diplexer **99** to the antenna element **95** to be transmitted at the desired down link frequency to ground station **88**. Filters and impedance matching devices have intentionally not been shown since such devices are well known in the art.

It can be seen from FIG. **10** that groups **88** and **89** may be used to form two beams associated with coverage of the Western portion of the U.S.A. as shown in FIG. 2, while groups **90** and **91** may produce 2 beams for the Central or Eastern areas. Similarly, the antenna elements of groups **88** through **91** or any desired number of groups can be programed or otherwise arranged to provide the twelve antenna patterns indicated in FIG. 2 as necessary to cover the irregular shape of the U.S.A. Likewise any desired number of beam patterns can be provided to provide the desired coverage of any irregularly shaped area. FIG. 10 also shows, for example, that a single conversion oscillator **120**, for signals transmitted by group **88**, can be coupled to all the mixing or convertor circuits associated with the exciter **105**, while different oscillators **107** through **109** are respectively coupled to the convertors associated with the exciters **111**, **115** and **121** for groups **89** through **91** respectively.

In the manner shown in FIG. 10, the antenna elements of the groups **88** through **91** can be multiplied to accommodate more beams and positioned within a reflector aboard a satellite or a plurality of reflectors to automatically transmit a received signal as a plurality of directed beam patterns to provide a desired coverage of an area which is determined by a beacon or transmitter located on the ground.

What is claimed is:

1. A method for confining communication coverage to substantially all of a predetermined irregularly shaped area located on the surface of a celestial body comprising the steps of:

(a) placing a satellite in a synchronous orbit about said celestial body and in view of said irregularly shaped area; and

(b) simultaneously radiating from said satellite a plurality of separate identical signals each of which has its own preselected radiation pattern that is at least substantially confined to some certain portion of said irregularly shaped area corresponding thereto, the respective radiation patterns of said separate identical signals being oriented in predetermined contiguous relationship with each other to form a composite radiation pattern which solely illuminates all of an area of said celestial body that is substantially congruent with said irregularly shaped area.

2. The method defined in claim **1**, further comprising the steps of:

(c) transmitting information signal to said satellite;

(d) receiving said information signal at said satellite; and

(e) providing each of said identical signals with the information contained in said information signal.

3. The method defined in claim 2, wherein said information signal is transmitted from said irregularly shaped area of said celestial body.

4. The method defined in claim 1, wherein said celestial body is earth.

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