

## **SATELLITE COMMUNICATIONS TERMINAL FOR A SHIP AND ASSOCIATED METHODS**

### **Related Application**

**[0001]** The present application is a continuation-in-part of U.S. Patent Application Serial No. 14/625,085, filed on February 18, 2015, which is a continuation-in-part of U.S. Patent Application Serial No. 14/608,790, filed on January 29, 2015, the entire disclosures of each of which is incorporated by reference herein.

### **Field of the Invention**

**[0002]** The present invention relates to the field of wireless communications, and more particularly, to a satellite communications terminal for a ship, and related methods.

### **Background**

**[0003]** When ships travel across large bodies of water, such as the ocean, they rely on satellite communications to maintain contact on shore. Satellites typically operate over multiple frequency bands, such as C-band and Ku-band, for example. The C-band provides a larger coverage area than the Ku-band. Since the Ku-band operates at a higher frequency than

the C-band, shorter wavelength signals are used. Consequently, the Ku-band provides spot beam coverage.

**[0004]** Ships generally include a multi-band satellite antenna assembly that operates over the C-band and the Ku-band. When an oil and gas exploration ship, rig, vessel or other device floating on water (herein referred to as a ship) is operating in the Gulf of Mexico, for example, the multi-band satellite antenna assembly is typically configured to operate in the Ku-band. The Ku-band may be preferred since operating costs are generally lower as compared to operating in the C-band. When the oil and gas exploration ship is traveling across the ocean to the North Sea, for example, the availability of the Ku-band is limited. Consequently, the multi-band satellite antenna assembly is configured to operate in the C-band.

**[0005]** In some embodiments, the multi-band satellite antenna assembly may not simultaneously support both C-band and Ku-band and needs to be manually configured for the desired frequency band. This requires the ship to be at port, and the reconfiguration can be a time consuming and costly process. In other embodiments, the multi-band satellite antenna assembly may simultaneously support both C-band and Ku-band so that manual reconfiguration is not required.

**[0006]** Continued growth and demand for bandwidth has led to new commercial satellite constellations at higher frequency. The O3b satellite constellation is a next generation of satellites that operate in the Ka-band. The Ka-band satellites are deployed in a medium earth orbit as compared to a geosynchronous orbit used by C-band/Ku-band satellite constellations. An advantage of a medium earth orbit is that latency times for voice and data communications are significantly reduced.

**[0007]** There are several multi-band satellite antenna assemblies that support Ku-band and Ka-band but not C-band. For example, U.S. patent no. 8,497,810 to Kits van Heyningen et al. discloses an antenna assembly implemented as a multi-beam, multi-band antenna having a main reflector with multiple feed horns and a subreflector having a reflective surface defining an image focus for a Ka-band signal and a prime focus for a Ku-band frequency signal. U.S. patent no. 8,334,815 to Monte et al. discloses an antenna assembly implemented as a multi-beam, multi-feed antenna having a primary reflector fitted with a dual mode feed tube and a switchable low noise feed block (LNB) that supports both Ka-band and Ku-band reception.

**[0008]** U.S. published patent application no. 2013/0295841 to Choi et al. discloses a satellite communication system between a source and a destination over multiple satellite communications paths. The satellite communication system first identifies the link performance established in multiple spectrums, then it performs a link comparison among the multiple spectrums (e.g., C-, Ku-, or Ka-Band) so as to determine a spectrum link that provides the highest throughput within an acceptable reliability criteria. The satellite communication system switches among the multiple spectrum links to provide the determined spectrum link between the source and the destination.

**[0009]** When a ship has potential access to multiple satellite networks, a determination may need to be made on which satellite network to select. Satellite network selection may be based upon a number of factors. In some instances, to reconfigure to a satellite network, changes to the antenna and associated circuitry have been made manually, and, typically when the ship is at a desired port.

### **Summary**

**[0010]** The embodiments disclosed herein are directed to a satellite communications terminal for a ship. The terminal may include an antenna comprising three antenna feeds operable at respective different frequencies, communications circuitry coupled to the three antenna feeds and being configurable for a selected antenna feed, and a positioner to mount the antenna to the ship and point the antenna. The terminal may also include a controller to select an antenna feed, configure the communications circuitry, and operate the positioner to point the antenna to a selected satellite all based upon the location of the ship and at least one selection rule. The controller comprises a processor and a memory coupled thereto, for example.

**[0011]** The at least one selection rule may comprise at least one of a communications circuitry configuration rule and a service level agreement rule. In somewhat different terms, the at least one selection rule may be based upon at least one of communication speed, communication latency, and communication cost.

**[0012]** The controller may store antenna pointing data for different satellite footprints and different ship locations. The controller may also operate the positioner according to the antenna pointing data. The satellites may be geostationary or non-geostationary.

**[0013]** The controller may select the antenna feed, configure the communications circuitry, and operate the positioner also based upon at least one of a communications circuitry status, and a time-of-day. Of course, time-of-day is relevant to non-geostationary satellites.

**[0014]** The controller and the antenna advantageously allows for seamless roaming across different satellite types, including geostationary and non-geostationary. The controller may select the appropriate frequency band, for example, depending on location of the ship, frequency band availability, topology and application.

**[0015]** The controller may comprise a remote override interface to permit a remote station to override at least one of selection of the antenna feed, configuration of the communications circuitry, and pointing of the antenna. In other words, although the terminal is generally autonomous, in some circumstances it may be desirable to override the satellite network being used at the ship.

**[0016]** In some embodiments, the antenna may comprise a main reflector cooperating with the three antenna feeds, and a subreflector spaced from the main reflector. For example, three antenna feeds may be operable at the Ka band, Ku band, and C band, respectively.

**[0017]** The communications circuitry may comprise a first transmitter and receiver pair associated with the first antenna feed, a second transmitter and receiver pair associated with the second antenna feed, and a third transmitter and receiver pair associated with the third antenna feed. The circuitry may also comprise a first modem associated with the first transmitter and receiver pair, a second modem associated with the second transmitter and receiver pair, and a third modem associated with the third transmitter and receiver pair. The different modems may be operable with different selectable configurations, for example. In addition, the communications circuitry may comprise a router associated with the first, second and third modems.

**[0018]** For some shipboard applications, the positioner may comprise a stabilization platform. A radome may also be provided to surround the antenna.

**[0019]** A method aspect is for operating a satellite communications terminal for a ship as described above. That is, the terminal may comprise an antenna comprising three antenna feeds operable at respective different frequencies, communications circuitry coupled to the three antenna feeds and being configurable for a selected antenna feed, and a positioner to mount the antenna to the ship and point the antenna. Accordingly, the method may comprise operating a controller to select an antenna feed, configure the communications circuitry, and operate the positioner to point the antenna to a selected satellite all based upon the location of the ship and at least one selection rule.

#### **Brief Description of the Drawings**

**[0020]** FIG. 1 is a perspective view of a satellite antenna assembly with three antenna feeds in accordance with the present invention.

**[0021]** FIG. 2 is a perspective view of the subreflector illustrated in FIG. 1 with respect to the first antenna feed and the second and third antenna feeds.

**[0022]** FIG. 3 is a front perspective view of the first antenna feed illustrated in FIG. 1.

**[0023]** FIG. 4 is a rear perspective view of the first antenna feed illustrated in FIG. 1.

**[0024]** FIG. 5 is a front perspective view of the second and third antenna feeds illustrated in FIG. 1 without the frequency selective surface (FSS) material.

[0025] FIG. 6 is a rear perspective view of the second and third antenna feeds illustrated in FIG. 1 without the FSS material.

[0026] FIG. 7 is a flowchart of a method for making the antenna assembly illustrated in FIG. 1.

[0027] FIG. 8 is a perspective view of another embodiment of a satellite antenna assembly with three antenna feeds in accordance with the present invention.

[0028] FIG. 9 is a front perspective view of the first antenna feed illustrated in FIG. 8 without the FSS material.

[0029] FIG. 10 is a rear perspective view of the first antenna feed illustrated in FIG. 8 without the FSS material.

[0030] FIG. 11 is a front perspective view of the second and third antenna feeds illustrated in FIG. 8.

[0031] FIG. 12 is a rear perspective view of the second and third antenna feeds illustrated in FIG. 8.

[0032] FIG. 13 is a flowchart of a method for making the antenna assembly illustrated in FIG. 8.

[0033] FIG. 14 is a block diagram of a satellite communications terminal for a ship in accordance with the present invention.

[0034] FIG. 15 is a simplified block diagram of the satellite communications terminal illustrated in FIG. 14 with multiple antenna assemblies.

[0035] FIG. 16 is a functional block diagram of the satellite communications terminal illustrated in FIG. 14.

[0036] FIG. 17 is a flowchart of a method for operating the satellite communications terminal illustrated in FIG. 14.

### **Detailed Description**

[0037] The present invention will now be described more fully hereinafter with reference to the accompanying drawings,

in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

**[0038]** Referring initially to FIG. 1, a satellite antenna assembly **20** with three antenna feeds will be discussed. The antenna assembly **20** includes a main reflector **30** and a subreflector **32** spaced from the main reflector. The subreflector **32** includes a frequency selective surface (FSS) material that is reflective for a first frequency band and transmissive for both a second frequency band and a third frequency band.

**[0039]** A first antenna feed **40** is adjacent the main reflector **30** and is directed toward the subreflector **32**. The first antenna feed **40** is for the first frequency band. Second and third antenna feeds **42**, **44** are arranged in a coaxial relationship and are directed toward the main reflector **30** with the subreflector **32** therebetween. The second and third antenna feeds **42**, **44** are for the second and third frequencies, respectively.

**[0040]** In the illustrated embodiment, the first frequency band is the Ka-band, the second frequency band is the Ku-band, and the third frequency band is the C-band. The first, second and third antenna feeds **40**, **42**, **44** may be simultaneously operable. Since selection of anyone of the three antenna feeds **40**, **42**, **44** may be done on the fly, this avoids the need for manually reconfiguring the antenna assembly to a desired frequency band. The satellite antenna assembly **20** is not

limited to these frequency bands. As readily appreciated by those skilled in the art, anyone of the antenna feeds **40**, **42**, **44** may be configured to operate at a different frequency band. In fact, a fourth frequency band could be added to the satellite antenna assembly **20**.

**[0041]** The satellite antenna assembly **20** includes a stabilization platform **50** coupled to the main reflector **30**. The stabilization platform **50** moves the main reflector **30** based on a desired azimuth and elevation. The stabilization platform **50** also maintains the main reflector **30** in the desired azimuth and elevation, such as in a shipboard application, as will be appreciated by those skilled in the art. The main reflector **30** is sized based on the operating frequencies of the antenna feeds, and typically has a diameter in a range of 2 to 3 meters, for example. A radome **60** covers the main reflector **30** and the subreflector **32**. The radome **60** is configured to be compatible with the first, second and third frequency bands. The illustrated radome **60** is shown partially cut-away to more clearly illustrate positioning of the the main reflector **30** and the subreflector **32**, as well as the first, second and third antenna feeds **40**, **42**, **44**.

**[0042]** Incorporating three antenna feeds **40**, **42**, **44** within the satellite antenna assembly **20** advantageously allows re-use of existing volume and mounting infrastructure already allocated for antenna assemblies operating with two antenna feeds. The three antenna feeds **40**, **42**, **44** also advantageously allow for additional bandwidth to be supported by the satellite antenna assembly **20**. This may be important for ships, as well as for land-based remote satellite terminals, for example, where installation space and accessibility may be limited. Each of the first, second and third antenna feeds may be operable for both transmit and receive.

**[0043]** The first, second and third antenna feeds **40**, **42**, **44** may be simultaneously operable. Since selection of anyone of the three antenna feeds may be done on the fly, this may avoid the need for manually reconfiguring the antenna assembly to a desired frequency band.

**[0044]** The main reflector **30** has a medial opening therein, and the first antenna feed **40** is configured as an antenna feed horn extending through the medial opening. The first antenna feed **40** is arranged in a Cassegrain configuration since it is aimed at the subreflector **32** that is reflective to the first frequency band.

**[0045]** As noted above, the subreflector **32** includes a FSS material that is reflective for the first frequency band (i.e., first antenna feed **40**) and is transmissive for both the second frequency band (i.e., second antenna feed **42**) and the third frequency band (i.e., third antenna feed **44**). For the first frequency band corresponding to the Ka-band, the FSS material is reflective to 17-29 GHz, where the receive frequency is 17-19.5 GHz and the transmit frequency is 27-29 GHz. For the second frequency band corresponding to the Ku-band, the FSS material is transmissive to 10-14.5 GHz, where the receive frequency is 10-12 GHz and the transmit frequency is 13.7-14.5 GHz. For the third frequency band corresponding to the C-band, the FSS material is transmissive to 3.9-6.5 GHz, where the receive frequency is 3.9-4.2 GHz and the transmit frequency is 5.9-6.5 GHz.

**[0046]** An enlarged view of the subreflector **32** is provided in FIG. 2. When the first antenna feed **40** is operating in the transmit mode, radio frequency (RF) signals from the first antenna feed are reflected by the subreflector **32** to the main reflector **30** which then directs the RF signal to a satellite. When the first antenna feed **40** is operating in the receive

mode, RF signals received by the main reflector **30** are reflected to the subreflector **32**, which then directs the RF signal to the first antenna feed **40**.

**[0047]** The first antenna feed **40** is mounted to a front antenna feed mounting plate **70**, as illustrated in FIGS. 3 and 4. Support rods **72** extend from the front antenna feed mounting plate **70** to a rear antenna feed mounting plate **74**. The front antenna feed mounting plate **70** is positioned in front of the main reflector **30**, whereas the rear antenna feed mounting plate **74** is positioned to the rear of the main reflector. Transmit and receive switches **76**, **78** are carried by the rear antenna feed mounting plate **74**. The transmit and receive switches **76**, **78** are coupled to a waveguide assembly **79**. Although not shown in the figures, an additional waveguide assembly is coupled to the transmit and receive switches **76**, **78**.

**[0048]** The waveguide assembly **79** thus interfaces with a low-noise block downconverter (LNB) for receiving RF signals in the first frequency band. The LNB is a combination of a low-noise amplifier, a frequency mixer, a local oscillator and an IF amplifier. The LNB receives the RF signals from the satellite as collected by the main reflector **30** and reflected by the sub-reflector **32**, amplifies the RF signals, and downconverts a frequency of the RF signals to an intermediate frequency (IF). The waveguide assembly **79** also interfaces with a block upconverter (BUC) for transmitting RF signals to the satellite. The BUC converts from an IF frequency to the desired operating frequency.

**[0049]** The second antenna feed **42** is configured as an elongated center conductor, and the third antenna feed **44** is configured as a series of stepped circular conductors surrounding and spaced apart from the elongated center

conductor, as best illustrated in FIGS. 5 and 6. The second and third antenna feeds **42, 44** are coupled to a waveguide assembly **80**. Similar to the waveguide assembly **79**, this waveguide assembly **80** interfaces with respective LNBS and BUCs for the second and third antenna feeds **42, 44**.

**[0050]** The second and third antenna feeds **42, 44** advantageously share the same physical space. The second and third antenna feeds **42, 44** are configured similar to a coaxial cable. The RF signals for the second antenna feed **42** travel down the inner conductor, whereas the RF signals for the third antenna feed **44** travel down the outer conductor.

**[0051]** The waveguide assembly **80** includes a rotatable base **82** mounting the second and third antenna feeds **42, 44** and the subreflector **32**. A plurality of struts **84** are coupled between the rotatable base **80** and the subreflector **32**. Gears **86** are used to rotate the second and third antenna feeds **42, 44** so that linear polarization is lined up properly with the satellite. The subreflector **32** also rotates with rotation of the second and third antenna feeds **42, 44**. Alternatively, the subreflector **32** may be configured so that it does not rotate with rotation of the second and third antenna feeds **42, 44**.

**[0052]** The second antenna feed **42** (i.e., Ku-band) only operates in linear polarization (vertical or horizontal). The third antenna feed **44** (i.e., C-band) operates in linear polarization (vertical or horizontal) or circular polarization (left hand or right hand circular polarization). When both the second and third antenna feeds **42, 44** are operating in linear polarization, then both feeds are rotated simultaneously until the proper linear polarization is lined up with the satellite.

**[0053]** If the third antenna feed **44** is operating in circular polarization, then rotation of the rotatable base **82** has no effect on the circular polarization. In other words,

circular polarization is not effected by linear polarization. To adjust for left hand or right hand circular polarization, a polarizer **88** is rotated.

**[0054]** The satellite antenna assembly **120** includes a stabilization platform **150** coupled to the main reflector **130**. The stabilization platform **150** moves the main reflector **130** based on a desired azimuth and elevation. The stabilization platform **150** also maintains the main reflector **130** in the desired azimuth and elevation, such as in a shipboard application, as will be appreciated by those skilled in the art. A radome **160** covers the main reflector **130** and the subreflector **132**. The radome **160** is configured to be compatible with the first, second and third frequency bands. The illustrated radome **160** is shown partially cut-away to more clearly illustrate positioning of the the main reflector **130** and the subreflector **132**, as well as the first, second and third antenna feeds **140**, **142**, **144**.

**[0055]** Referring now to the flowchart **100** illustrated in FIG. 7, a method for making an antenna assembly **20** as described above will be discussed. From the start (Block **102**), the method comprises positioning a subreflector **32** spaced from a main reflector **30** at Block **104**, with the subreflector comprising a frequency selective surface (FSS) material that is reflective for a first frequency band and transmissive for both a second frequency band and a third frequency band. A first antenna feed **40** is positioned adjacent the main reflector **30** at Block **106** so as to be directed toward the subreflector **32**. The first antenna feed **40** is for the first frequency band. Second and third antenna feeds **42**, **44** are arranged in a coaxial relationship and are positioned at Block **108** so as to be directed toward the main reflector **30** with the subreflector **32** therebetween. The second and third antenna

feeds **42**, **44** are for the second and third frequencies, respectively. The method ends at Block **110**.

[0056] Referring now to FIG. 8, another embodiment of a satellite antenna assembly **120** will be discussed where positioning of the antenna feeds is reversed. The elements in this embodiment are similar to the elements in the above described satellite antenna assembly **20**, and are numbered in the hundreds. Descriptions of the elements in the satellite antenna assembly **20** are applicable to corresponding elements in the satellite antenna assembly **120**, except where noted. In addition, the features and advantages of the first embodiment of the antenna assembly **20** are also applicable to this embodiment **120** as well.

[0057] The antenna assembly **120** includes a main reflector **130** and a subreflector **132** spaced from the main reflector. The subreflector **132** includes a frequency selective surface (FSS) material that is transmissive for a first frequency band and reflective for both a second frequency band and a third frequency band.

[0058] A first antenna feed **140** is adjacent the subreflector **132** and is directed towards the main reflector **130**. The first antenna feed **140** is for the first frequency band. Second and third antenna feeds **142**, **144** are arranged in a coaxial relationship adjacent the main reflector **130** and are directed toward the subreflector **132**. The second and third antenna feeds **142**, **144** are for the second and third frequency bands, respectively.

[0059] A mounting plate **174** mounts the first antenna feed **140**, and struts **172** are coupled between the mounting plate and the subreflector **132**. The first antenna feed **140** is positioned between the mounting plate **174** and the subreflector **132**. In

other words, the first antenna feed **140** is behind the subreflector **132**.

[0060] Front and rear perspective views of the first antenna feed **140** without the subreflector **132** are provided in FIGS. 9 and 10. Additional struts **173** are coupled between the mounting plate **174** and the first antenna feed **140**.

[0061] The first antenna feed **140** is configured as an antenna feed horn. Transmit and receive switches **176**, **178** are carried by the rear of the mounting plate **174**. A waveguide assembly **179** is coupled between the transmit and receive switches **176**, **178** and the first antenna feed **140**. Although not shown in the figures, an additional waveguide assembly is coupled to the transmit and receive switches **176**, **178**.

[0062] The second antenna feed **142** is configured as an elongated center conductor, and the third antenna feed **144** is configured as a series of stepped circular conductors surrounding and spaced apart from the elongated center conductor, as best illustrated in FIGS. 11 and 12. The second and third antenna feeds **142**, **144** are coupled to a waveguide assembly **180**.

[0063] The waveguide assembly **180** includes a rotatable base **182** mounting the second and third antenna feeds **142**, **144**. Struts **181** are coupled between the rotatable base **182** and the second and third antenna feeds **142**, **144**. Gears **186** are used to rotate the second and third antenna feeds **142**, **144** so that linear polarization is lined up properly with the satellite.

[0064] If the third antenna feed **144** is operating in circular polarization, then rotation of the rotatable base **182** has no effect on the circular polarization. In other words, circular polarization is not effected by linear polarization. To adjust for left hand or right hand circular polarization, a polarizer **188** is rotated.

**[0065]** Referring now to the flowchart **200** illustrated in FIG. 13, a method for making an antenna assembly **120** as described above will be discussed. From the start (Block **202**), the method comprises positioning a subreflector **132** spaced from a main reflector **130** at Block **204**, with the subreflector comprising an FSS material that is transmissive for a first frequency band and reflective for both a second frequency band and a third frequency band. A first antenna feed **140** is positioned at Block **206** so as to be directed toward the main reflector **130**, with the first antenna feed being carried by the subreflector **132**. The first antenna feed **140** is for the first frequency band. Second and third antenna feeds **142**, **144** arranged in a coaxial relationship are positioned at Block **208** adjacent the main reflector **130** so as to be directed toward the subreflector **132**. The second and third antenna feeds **142**, **144** are for the second and third frequency bands, respectively. The method ends at Block **210**.

**[0066]** Another aspect is directed to a satellite communications terminal **400** for a ship, as illustrated in FIG. 14. The ship may be any structure that floats on water, including, but limiting to, oil and gas exploration ships, passenger vessels, cruise lines, and military vessels, for example. The satellite communications terminal **400** includes an antenna **410** comprising three antenna feeds **412**, **414**, **416** operable at respective different frequencies. Communications circuitry **420** is coupled to the three antenna feeds and is configurable for a selected antenna feed. The antenna **410** and the communications circuitry **420** are based on either one of the above described satellite antenna assemblies **20**, **120**, for example.

**[0067]** A positioner **440** mounts the antenna **410** to the ship and points the antenna. A controller **460** is used to select an

antenna feed, configure the communications circuitry **420**, and operate the positioner **440** to point the antenna **410** to a selected satellite all based upon the location of the ship and one or more selection rules **470**.

**[0068]** The controller **460** may also be referred to as an integrated call director (ICD) since it is aware of the operator's communications traffic and handles the routing of communications traffic on and off the ship. The controller **460** is a geographically aware smartbox that recognizes where the antenna **410** is around the world, and carries a map database **466** of the satellite network footprints that are available.

**[0069]** The controller **460** and multi-band antenna **410** advantageously allows for seamless roaming across all satellite types, including geostationary and non-geostationary. The controller **460** selects the appropriate frequency band depending on location of the ship, frequency band availability, topology and application. The different types of satellites operate over separate frequency bands, such as Ka-band, Ku-band, and C-band, for example.

**[0070]** Frequency band and satellite selection by the controller **460** may be based on a plurality of different inputs, such as what capacity is available, what frequency band provides the best application performance, what frequency band provides the best resilience, what frequency band results in compliance to a regulator's requirement with respect to allowable transmission frequencies. The controller **460** may thus route the ship's communications traffic intelligently over the most appropriate satellite network path based on speed, latency, location and cost. By optimizing the satellite network traffic, the controller **460** advantageously enhances the end-to-end experience with an intelligent routing approach that provides end-to-end application performance management.

**[0071]** The controller **460** also allows for the ability to mitigate interferences or boost network speeds by using two or more frequency bands simultaneously. In addition to satellite communications, the controller **460** includes the capability to integrate other transport technologies, such as wireless systems including cellular and WiFi communications, for example, so as to optimize client experience and application performance by accessing any available transport path in a given location. In some embodiments, fiber optics may also be supported.

**[0072]** The illustrated antenna **410** with three antenna feeds includes a first antenna feed **412**, a second antenna feed **414** and a third antenna feed **416**. The first antenna feed **412** is for the Ka-band, the second antenna feed **414** is for the Ku-band, and the third antenna feed **416** is for the C-band. The first, second and third antenna feeds **412**, **414**, **416** may be simultaneously operable. Since selection of anyone of the three antenna feeds **412**, **414**, **416** may be done on the fly, this may avoid the need for manually reconfiguring the antenna assembly to a desired frequency band at a desired port. The antenna **410** is not limited to these frequency bands. As readily appreciated by those skilled in the art, anyone of the antenna feeds **412**, **414**, **416** may be configured to operate at a different frequency band. In other embodiments, additional frequency bands may be supported by the antenna **410**.

**[0073]** The illustrated communications circuitry **420** includes a respective transmitter and receiver pair associated with each antenna feed. A first transmitter and receiver pair **422** is coupled to the first antenna feed **412**. A second transmitter and receiver pair **424** is coupled to the second antenna feed **414**. A third transmitter and receiver pair **426** is coupled to the third antenna feed **416**.

[0074] Each transmitter and receiver pair has a respective modem associated therewith. A first modem **432** is coupled to the first transmitter and receiver pair **422**. A second modem **434** is coupled to the second transmitter and receiver pair **424**, and a third modem **436** is coupled to the third transmitter and receiver pair **426**. A router **438** is coupled to the first, second and third modems **432**, **434**, **436**.

[0075] The antenna **410** includes a main reflector cooperating with the three antenna feeds **412**, **414**, **416**, and a subreflector spaced from the main reflector. The positioner **440** includes a stabilization platform **442**. The stabilization platform **442** moves the main reflector based on a desired azimuth and elevation. The stabilization platform **442** also maintains the main reflector in the desired azimuth and elevation, which is important in a shipboard application, as will be appreciated by those skilled in the art.

[0076] The controller **460** further includes a remote override interface **481** to permit a remote station to override at least one of selection of the antenna feed **412**, **414**, **416**, configuration of the communications circuitry **420**, and pointing of the antenna **410**. In other words, although the satellite communications terminal **400** is generally autonomous, in some circumstances it may be desirable to override the satellite network being used at the ship. The remote override interface **481** also permits an operator on board the ship to override the controller **460**.

[0077] To avoid signal blockage with a desired satellite as a result of where the antenna **410** is located on the ship, a ship typically multiple antennas, as illustrated in FIG. 15. For example, antenna **410(1)** may be located on the port side, antenna **410(2)** may be located on the starboard side, and antenna **410(3)** may be located forward of the ship. The

multiple antennas **410(1)**, **410(2)**, **410(3)** form an antenna bank **408**.

**[0078]** With multiple antennas **410(1)**, **410(2)**, **410(3)** the satellite communications terminal **400** further includes a matrix switch **451** that is controlled by the controller **460** for selecting which one of the antennas to use. An antenna manager interface **453** is coupled to the router **438** and to the controller **460**. The antenna manager interface **453** also allows for a manual override of the controller **460**.

**[0079]** The controller **460** includes a processor **462** and a memory **464** coupled thereto. The map database **466** of the satellite network footprints is stored in the memory **464**. As noted above, the controller **460** operates the positioner **440** to point the antenna **410** to a selected satellite so as to route the ship's communications traffic intelligently over the most appropriate satellite network path based on number of different variables, such as location of the ship and one or more selection rules **470**. The selection rules **470** are also stored in the memory **464**.

**[0080]** The location of the ship may be determined by GPS **480**, for example. The selection rules **470** may be based on communications speed, communications latency, and/or communications cost. The selection rules **470** may also be based on a communications circuitry configuration rule and/or a service level agreement rule.

**[0081]** For the communications circuitry configuration rule, location of the ship verses available network options are taken into consideration when selecting the transmitter and receiver pair and corresponding antenna feed. For the service level agreement rule, service criteria such as quality of service (QoS) and bit rates are taken into consideration when

selecting the transmitter and receiver pair and corresponding antenna feed.

**[0082]** Operation of anyone of the three antenna feeds **414**, **416**, **418** has performance and communication cost criteria associated therewith. For the performance criteria, this includes speed and communication latency. For example, the O3b satellite constellation is a next generation of satellites that operate in the Ka-band. The Ka-band satellites are deployed in a medium earth orbit as compared to a geosynchronous orbit used by C-band/Ku-band satellite constellations. An advantage of a medium earth orbit is that latency times for voice and data communications are significantly reduced. Each one of these different satellite types has a communication cost factor associated therewith. The circuitry configuration rule may thus be used to select a particular transmitter and receiver pair and corresponding antenna feed.

**[0083]** The controller **460** also stores antenna pointing data for different satellite footprints at different ship locations in the memory **464**, and operates the positioner **440** according to the antenna pointing data. The controller **460** selects the antenna feed **412**, **414**, **416**, configures the communications circuitry **420**, and operates the positioner **440** also based upon a communications circuitry status and/or a time-of-day. The time-of-day is relevant to non-geostationary satellites.

**[0084]** A functional block diagram **490** of the satellite communications terminal **400** will now be discussed with reference to FIG. 16. In the functional block diagram, the satellite communications terminal **400** for the ship interfaces with multiple on-shore locations **500**, **510**.

**[0085]** One on shore location **500** stores a master map database **502** of the satellite network footprints that are

available. This allows for real time network availability lookup **571**. The map database **466** of the satellite network footprints as stored in the controller **460** is also periodically synchronized with the on shore master map database **502** for updates.

**[0086]** Another on shore location **510** includes network management equipment **512** that receives notification when a change is made from a current communications circuitry and corresponding antenna feed to a different communications circuitry and corresponding antenna feed. The network management equipment **512** is configured for reference and troubleshooting purposes. In addition, additional network usage metrics may be delivered periodically to the management equipment **512** to facilitate further analysis on network path utilization and cost management. Communications between the satellite communications terminal **400** and the on shore locations **500**, **510** is via a secure encrypted link as background traffic via the available paths.

**[0087]** Functionally the controller **460** includes a selection rules module **530** and a trigger module **532**. Events **540**, position **542** of the ship, and time **544** are provided to the trigger module **532**. The events **540** correspond to system faults, antenna obstructions and network alarms, for example. Position **542** of the ship may be provided by a GPS device **480**, for example. Time-of-day **544** may be provided by a timer or clock, for example.

**[0088]** A service level agreement module **550** and an equipment configuration module **552** interface with the selection rules module **530**. The selection rules module **530** operates based upon a set of selection rules to select the appropriate frequency band.

**[0089]** The controller **460** assesses location **542** of the ship against available network options by querying the locally held map database **466**. Information from the map database **466** is used by the selection rules module **530** which reconfigures the hardware **560** as necessary. For example, the change may be from the second antenna feed (e.g., Ku-band) to the third antenna feed (e.g., C-band). This requires reconfiguring the antenna **410** and communications circuitry **420** with the appropriate satellite modem parameters so as to enter the corresponding network. These parameters are identified in functional block **573**. As part of the reconfiguring process reference is made to information stored in the site service level agreement module **550** and the equipment capabilities module **552**.

**[0090]** The network traffic from the ship then self adapts by application priority using performance routing, such as Cisco's PfRv3 performance routing. Performance routing monitors application performance on a per flow basis, and applies what is learned to select the best path for that application. Using smart-probe intelligence, flows may be monitored passively. Probes may be sent only when specifically needed to further enhance efficiency. Performance routing effectively load balances across multiple paths while delivering the best application level service level agreement. Performance routing provides intelligent path control for application-aware routing. A graphical user interface **570** with manual override is provided to allow engineers to directly monitor and control the hardware **560** (i.e., antenna **460** and communications circuitry **420**).

**[0091]** A flowchart **600** for operating the satellite communications system **400** for a ship will now be discussed in reference to FIG. 17. From the start **602**, a fixed remote attributes query is performed at Block **604** against map

configuration attributes for hardware supporting networks. A clear look angle is then determined at Block **606** based on location of the ship, satellite locations and configured blockage zones. Look angle calculations are performed at Block **608** and are provided to Block **606**. Map database configuration attributes are updated at Block **610**.

[0092] Valid remote networks are created at Block **612** from the above query results. The currently selected network is queried at Block **614** against valid networks. Blocks **604**, **606**, **610**, **612** and **614** may also interface with a remote database at Block **616** to access different attributes and network information as needed. The remote database at Block **616** may also be updated with site hardware configuration at Block **618** and with a master map database at Block **620**. This update may be performed over a wireless area network (WAN) **622**. In addition, external locally gathered data may be provided to the remote database at Block **624**. The data includes network link qualities, headings and blockage zones, for example.

[0093] A determination is made at block **630** if the currently selected network is a valid network. If yes, then a determination is made at block **632** if the current network selection has an up status. If yes, then a determination is made at block **634** if the current network link quality is above a threshold. If yes, then a determination is made at Block **636** if the current network is the lowest cost network. If Yes, then the method ends at Block **660**.

[0094] Referring back to Block **630**, if the currently selected network is not a valid network, then a new network with the lowest cost is selected at Block **638**. Next, at Block **640**, an array of parameters is passed to external software hooks for switching to the new network. This involves updating the BDU (below deck controller) configuration at Block **642** and

updating the modem configuration at Block **644**. After the updates, the method ends at Block **660**.

**[0095]** Referring back to Block **632**, if the current network selection status is not up, then a determination is made at Block **646** as to whether the network has been down greater than a threshold. If yes, then a determination is made at Block **648** if the network is the lowest cost. If the network is not the lowest cost, then a new network is defined at Block **638**. If the network is the lowest cost, then the next lowest cost network is selected at Block **650**. The parameters and configuration for the new network are then updated at Blocks **640**, **642** and **644**. The method ends at Block **660**.

**[0096]** Referring back to Block **634**, if the current network link quality is below the threshold, then a determination is made at Block **648** if the current network is the lowest cost. Referring back to Block **636**, if the current network is not the lowest cost, then a determination is made at Block **652** if the cost difference between the lowest cost network is greater than a threshold. If the determination is yes, then a new network with the lowest cost is defined at Block **638**. If the determination is no, then the method ends at Block **660**.

**[0097]** As readily appreciated by those skilled in the art, the above flowchart may also be characterized as operating the controller **460** to select an antenna feed **412**, **414**, **416**, configure the communications circuitry **420**, and operate the positioner **442** to point the antenna **410** to a selected satellite all based upon the location of the ship and at least one selection rule.

**[0098]** Many modifications and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is

understood that the invention is not to be limited to the specific embodiments disclosed, and that modifications and embodiments are intended to be included within the scope of the appended claims.

**THAT WHICH IS CLAIMED IS:**

1. An antenna assembly comprising:

a main reflector;

a subreflector spaced from said main reflector and comprising a frequency selective surface (FSS) material that is reflective for a first frequency band and transmissive for both a second frequency band and a third frequency band;

a first antenna feed adjacent said main reflector and directed toward said subreflector, said first antenna feed for the first frequency band; and

second and third antenna feeds arranged in a coaxial relationship and directed toward said main reflector with said subreflector therebetween, said second and third antenna feeds for the second and third frequencies, respectively.

2. The antenna assembly according to Claim 1 wherein said main reflector has a medial opening therein; and wherein said first antenna feed comprises an antenna feed horn extending through the medial opening.

3. The antenna assembly according to Claim 1 wherein said second antenna feed comprises an elongated center conductor; and wherein said third antenna feed comprises a series of stepped circular conductors surrounding and spaced apart from said elongated center conductor.

4. The antenna assembly according to Claim 1 wherein the first frequency band comprises the Ka frequency band, the second frequency band comprises the Ku band, and the third frequency band comprises the C band.

5. The antenna assembly according to Claim 1 wherein each of said first, second and third antenna feeds are operable for both transmit and receive.

6. The antenna assembly according to Claim 1 wherein said first, second and third antenna feeds are simultaneously operable.

7. A method for making an antenna assembly comprising:

positioning a subreflector spaced from a main reflector, the subreflector comprising a frequency selective surface (FSS) material that is reflective for a first frequency band and transmissive for both a second frequency band and a third frequency band;

positioning a first antenna feed adjacent the main reflector so as to be directed toward the subreflector, the first antenna feed for the first frequency band; and

positioning second and third antenna feeds arranged in a coaxial relationship so as to be directed toward the main reflector with the subreflector therebetween, the second and third antenna feeds for the second and third frequencies, respectively.

8. The method according to Claim 7 wherein the main reflector has a medial opening therein; and wherein the first antenna feed comprises an antenna feed horn extending through the medial opening.

9. The method according to Claim 7 wherein the second antenna feed comprises an elongated center conductor; and wherein the third antenna feed comprises a series of

stepped circular conductors surrounding and spaced apart from the elongated center conductor.

10. The method according to Claim 7 wherein the first frequency band comprises the Ka frequency band, the second frequency band comprises the Ku band, and the third frequency band comprises the C band.

11. An antenna assembly comprising:

a main reflector;

a subreflector spaced from said main reflector and comprising a frequency selective surface (FSS) material that is transmissive for a first frequency band and reflective for both a second frequency band and a third frequency band;

a first antenna feed adjacent said subreflector and directed toward said main reflector, said first antenna feed for the first frequency band; and

second and third antenna feeds arranged in a coaxial relationship adjacent said main reflector and directed toward said subreflector, said second and third antenna feeds for the second and third frequency bands, respectively.

12. The antenna assembly according to Claim 11 wherein said main reflector has a medial opening therein; and wherein said second and third antenna feeds extend through the medial opening.

13. The antenna assembly according to Claim 11 wherein said first antenna feed comprises an antenna feed horn, said second antenna feed comprises an elongated center conductor, and said third antenna feed comprises a series of stepped circular conductors surrounding and spaced apart from said elongated center conductor.

14. The antenna assembly according to Claim 11 wherein the first frequency band comprises the Ka frequency band, the second frequency band comprises the Ku band, and the third frequency band comprises the C band.

15. The antenna assembly according to Claim 11 wherein each of said first, second and third antenna feeds are operable for both transmit and receive.

16. A method for making an antenna assembly comprising:

positioning a subreflector spaced from a main reflector, the subreflector comprising a frequency selective surface (FSS) material that is transmissive for a first frequency band and reflective for both a second frequency band and a third frequency band;

positioning a first antenna feed so as to be directed toward the main reflector, with the first antenna feed adjacent the subreflector, the first antenna feed for the first frequency band; and

positioning second and third antenna feeds arranged in a coaxial relationship adjacent the main reflector so as to be directed toward said subreflector, the second and third antenna feeds for the second and third frequency bands, respectively. .

17. The method according to Claim 16 wherein the main reflector has a medial opening therein; and wherein the second and third antenna feeds extend through the medial opening.

18. The method according to Claim 16 wherein the first antenna feed comprises an antenna feed horn, the second antenna feed comprises an elongated center conductor, and the third antenna feed comprises a series of stepped circular conductors surrounding and spaced apart from the elongated center conductor.

19. The method according to Claim 16 wherein the first frequency band comprises the Ka frequency band, the second frequency band comprises the Ku band, and the third frequency band comprises the C band.

20. The method according to Claim 16 wherein each of the first, second and third antenna feeds are operable for both transmit and receive.

21. A satellite communications terminal for a ship and comprising:

an antenna comprising three antenna feeds operable at respective different frequencies;

communications circuitry coupled to said three antenna feeds and being configurable for a selected antenna feed;

a positioner to mount said antenna to the ship and point said antenna; and

a controller to select an antenna feed, configure said communications circuitry, and operate said positioner to point said antenna to a selected satellite all based upon the location of the ship and at least one selection rule.

22. The satellite communications terminal according to Claim 21 wherein the at least one selection rule

comprises at least one of a communications circuitry configuration rule and a service level agreement rule.

23. The satellite communications terminal according to Claim 21 wherein the at least one selection rule is based upon at least one of communication speed, communication latency, and communication cost.
24. The satellite communications terminal according to Claim 21 wherein said controller stores antenna pointing data for different satellite footprints and different ship locations, and operates said positioner according to the antenna pointing data.
25. The satellite communications terminal according to Claim 21 wherein said controller selects the antenna feed, configures said communications circuitry, and operates said positioner also based upon at least one of a communications circuitry status and a time-of-day.
26. The satellite communications terminal according to Claim 21 wherein said controller comprises a remote override interface to permit a remote station to override at least one of selection of the antenna feed, configuration of said communications circuitry, and pointing of said antenna.
27. A method for operating a satellite communications terminal for a ship comprising an antenna comprising three antenna feeds operable at respective different frequencies, communications circuitry coupled to the three antenna feeds and being configurable for a selected

antenna feed, and a positioner to mount the antenna to the ship and point the antenna, the method comprising: operating a controller to select an antenna feed, configure the communications circuitry, and operate the positioner to point the antenna to a selected satellite all based upon the location of the ship and at least one selection rule.

28. The method according to Claim 27 wherein the at least one selection rule comprises at least one of a communications circuitry configuration rule and a service level agreement rule.

29. The method according to Claim 27 wherein the at least one selection rule is based upon at least one of communication speed, communication latency, and communication cost.

30. The method according to Claim 27 comprising operating the controller to store antenna pointing data for different satellite footprints and different ship locations, and operate the positioner according to the antenna pointing data.