At just under 24 inches in diameter, Intellian's v60 is designed for smaller recreational and commercial vessels. It can acquire and lock on to a satellite without requiring a separate input from the ship's gyrocompass.

VSAT

Use expands as antenna size shrinks and data speed accelerates

In recent years we've seen an increasing number of those distinctive white domes among the array of communications and navigation equipment on yacht masts and radar arches. Typically, one dome will receive satellite TV signals and the other will send and receive phone and data communications.

By Peter A. Robson

Once almost exclusively the domain of megayachts and commercial ships, a new generation of satellite voice and data communications systems has emerged in recent years. Known as VSAT (Very Small Aperture Terminal), these systems feature smaller antennas, higher data rates, lower airtime costs and are more reliable and easier to install than traditional systems.

The growth in the VSAT market has come from yachts and commercial vessels that travel beyond the reach of cellular networks and need access to features such as always-on high-speed Internet, email, voice communications and other functions such as sharing photos and video conferencing. VSAT customers range from commercial crab boats in the Bering Sea to yacht owners travelling the world who must continue to run their businesses while at sea.

One indicator of the demand for VSAT is reflected by the 26% increase in revenues for satellite antenna manufacturer KVH between 2009 and 2010, despite the economic downturn. According to KVH's Chris Watson, the satellite TV side of the business was flat over that period and more than half of the increase came from mobile communications satellite systems with VSAT sales leading the way.

What is VSAT?

Traditionally, most vessels have used voice and data communications services from global satellite giant Inmarsat. Known as FleetBroadband, the service uses a constellation of three fixed orbit (geostationary) satellites. Due to the way they are positioned, Inmarsat's FleetBroadband antennas only have to be aimed to within about 5 degrees of their satellites (compared to about 1 degree with other satellites), which makes them less expensive (starting at $7,500). The downside is the lower carrying capacity of the 1 to 2 GHz L-band frequency used by Inmarsat means that the company must charge very high rates for the service (about $12 per MB of data transmitted or received).

VSAT technology was first developed for land-based companies, then transitioned into the marine industry. VSAT systems use higher frequencies which make it possible to transmit up to 10 times the data (or 10 times the speed) as L-band satellites systems, which means they can do so at about 1/10th the cost of Inmarsat. The problem is that most of the hundreds of fixed orbit satellites compatible with VSAT systems are packed more tightly in the sky and require more precisely aimed antennas (to within one degree), which initially translated to very expensive (about $45,000) and large (3 feet or more in diameter) antennas. Today however, VSAT antennas produced by KVH are as small as 15 inches in diameter and cost as little $17,000. While this is comparable to Inmarsat's high-end hardware, the significantly lower service (airtime) costs makes it more affordable.

Looking Back

The industry has come a long way since the Russians launched the world's first communications satellite, Sputnik 1, in 1957. The USA wasn't far behind, and in the 1960s, NASA, the US Department of Defense and private companies such as AT&T, RCA and Hughes Aircraft all got into the business (and most are still in it). Initially, government and industry worked together to develop and regulate commercial and international satellite communications systems through jointly owned corporations such as COMSAT and the International Maritime Satellite Organization. Most of those have now become, or at least spawned, private entities such as Intelsat and Inmarsat.

As with the personal computer industry, the satellite industry has seen skyrocketing technological advances and today's antenna systems are smaller, more versatile and more reliable than ever.

Over the years, two distinct satellite technologies emerged. One is based on the use of fast-moving low-earth-orbit satellites (altitudes of less than about 1,250 miles). These satellites revolve around the globe about every 90 minutes and have proven very effective for voice communications constellations for companies such as Iridium and Globalstar, though they are not designed for sending and/or receiving large data files. Their handheld satellite phones use omni-directional antenna systems, which means they don't have to be "aimed" at a specific satellite.

The other system is based on geostationary, or fixed, satellites located at altitudes of 22,236 miles above the equator. A geostationary orbit (GEO) is one in which the satellite revolves at the same speed as the earth. To an observer on the ground, the satellite appears stationary in the sky at all times. Because of its high altitude, a single satellite can view about one-third of the earth's surface (i.e. both North and South America) at any given time. However, due to their location above the equator and the curvature of the earth, geostationary satellites cannot "see" the polar regions because they are out of the "line of sight." However, because the satellites appear stationary in the sky, ground antennas can be "fixed" into position so they always point at a specific satellite (in the same way our home satellite TV antennas always point to the appropriate broadcast satellite).

Geostationary satellites have proven much more effective for high-speed data communications because narrower and higher-frequency microwave "beams" can be focused on the stationary satellite for faster data speeds. But for communications systems using geostationary satellites, ground (or shipboard) antennas must be "aimed" to within 1 to 1.5 degrees of the satellite. This is easy to accomplish on land where antennas can be fixed in place, but on a constantly moving vessel, it is much more difficult. The problem was solved in 1978, when Sea Tel developed the world's first gyroscopically stabilized antenna. Others soon embraced the technology, though early maritime antennas were receive-only units limited to viewing television while at sea.

The first "small" commercially viable marine/mobile send-and-receive units came into widespread use in the 1980s by the oil and shipping industries as well as the military and government. However, it wasn't long before they found their way into the consumer market.

Sea Tel's 10-series of Ku-band antennas are built for vessels 100 feet and longer. The company pioneered the development of stabilized antenna technology.

KVH's TracPhone V3 is the smallest marine VSAT antenna, measuring 14.5 inches in diameter. It offers speeds of 2 mbps ship-to-shore and 128 kbps shore-to-ship.

Early satellite communications systems used what is known as single carrier per channel (SCPC) technology. Each ground or mobile station was assigned a unique send (and receive) frequency and bandwidth (data rate). And since there were a limited number of frequencies available, two-way satellite communications were very expensive and out of the reach of the average yacht owner.

Next came multiple channels per carrier (MCPC) technology, where the data from several carriers was combined into a single channel, then transmitted to a single location where it is recombined and sent to the individual destinations.

Most VSAT systems using antenna domes larger than 1 meter in diameter use IP-based Time Division Multiple Access technology (TDMA). Modem manufacturers offering this technology include Hughes, Comsys and iDirect. This allows bandwidth to be allocated and shared by multiple users by transmitting occasional short packet bursts in between other users, similar to how cellphones share cell towers. By sharing bandwidth, both TDMA and MCPC have lowered the cost for airtime and made it more affordable for smaller users.

Despite this, some business users—typically those who are heavy satellite airtime users, still prefer to own dedicated frequencies so any potential congestion remains under their local control. Companies such as radio stations that broadcast continuously also use SCPC.

Regardless of whether using dedicated or shared access, over recent years numerous innovations have increased the capacity and speed of satellite communications.

There are 800 or so satellites orbiting the earth. In addition to broadcasting TV signals and sending and receiving voice and data, satellites are also used for global positioning systems (GPS), radio broadcasting, weather, imaging, remote sensing, research and various military purposes.

Marine VSAT

Unlike land-based antennas, marine satellite antennas must have internal stabilizing mechanisms to keep their antennas pointed to the appropriate satellite regardless of the vessel's pitch, roll and yaw.

A shipboard VSAT system is relatively simple (at least in appearance). It consists of an antenna dish, known as the outdoor (or above deck) unit; and an indoor unit consisting of a control unit (to position the antenna) and a modem that converts voice, data, pictures and video from satellite to IP protocols (and vice versa) to allow the information to be displayed on a computer, local area network or telephone. And, of course, the system needs power, associated wiring as well as a computer, keyboard and screen.

Satellite Communications

The primary function of a communications satellite is to act as a microwave repeater to receive and re-transmit radio signals. Its elements include a power source (typically solar panels); batteries, a fuel supply and propulsion devices to keep the satellite on station and properly oriented; a number of transponders that change the uplink frequency to the downlink frequency and amplify the signal; and associated switching and processing controls. The communications capacity of a given satellite is based on the number of transponders and transponder channels it is fitted with and the volume of data that can be transmitted on each channel. Today's transponders have between 24 and 72 transponders and can handle up to 155 million bits of information per second. The average lifespan of a communications satellite is about 10 to 15 years.

The Satellite Network

When a vessel transmits data or voice, the signals are relayed up to the appropriate satellite and then back down to an earth station (or teleport) that could be in one of many countries depending on the vessel's location. The signals are then converted back into applications for Internet, VoIP (Voice over Internet Protocol) and data.

From the earth station, equipment sends data out through one of several network configurations to the appropriate IP address. When sending data to another vessel, the network transmits the data up to the satellite, down to the earth station, back up to the appropriate satellite and then down to the target vessel.

VSAT Antennas

A closer look at the equipment makers

There are three major VSAT antenna manufacturers: Sea Tel, Intellian Technologies, and KVH. At various times, these companies have distribution agreements with other companies. For example, KVH provides hardware for Thrane & Thrane, Furuno and JRC.

Intellian Technologies: Based in Irvine, CA, Intellian manufactures a wide range of mobile satellite communications hardware, including VSAT, TV and Fleet Broadband antennas.

Its most recent VSAT antenna is the v60 with a 60 centimeter (23.6 inches) dish. It is the smallest, most compact antenna the company offers. It weighs 121 lbs (60 kg) and was designed specifically for smaller recreational and commercial vessels. The antenna has an internal GPS and what the company calls Gyro-free Satellite Search Capability. This function enables the v60 to acquire and lock onto a satellite without requiring a separate input from the ship's gyrocompass. The GPS provides an initial position and then determines where to "look" for the satellite (direction and elevation). It then searches in a narrowing pattern until it can lock onto the signal. From that point on, it uses the signal from the satellite to control the movement of the antenna.

The v60 uses the Ku-band and offers download speeds of up to 1.5 mbps and VoIP. Airtime plans are available from a variety of service providers. The v60 retails for about $26,000 (not including the modem, which will add about $8,000 to the price).

Intellian's V-series also includes the larger v110 antenna (1.05 meter diameter) and the v130 (1.3 meter diameter). These use the same technology as the v60, but their larger antenna dishes means they receive stronger signals and therefore faster data throughput (1 to 4 mpbs). The larger dishes also allow vessels to communicate better in areas where there are weaker satellite signals.

Sea Tel: Sea Tel is a division of Cobham Plc. Founded in 1978, Sea Tel claims says it is the world's largest manufacturer of commercial shipboard stabilized antenna platforms for satellite communications, television and weather systems. Sea Tel was the first company to develop a gyroscopically stabilized satellite antenna.

In the company's early years, its satellite antennas were very large and suitable only for big ships. However, over the years, and thanks to the increased power of modern satellites, Sea Tel has been able to produce much smaller dishes and systems for marine applications. The company says its strengths are in the equipment's exceptional reliability, tracking and support through its worldwide dealer network.

Sea Tel says its antennas are designed to the highest military and IEC standards for protection against vibration and shock and have a reliability rate of 99.99%. If there is a problem, the company's remote software can remotely access and diagnose the system. Their VSAT antenna stabilization system uses an inertial reference platform (inertial navigational system) incorporating a computer and motion sensors (accelerometers, and rate sensors) to continuously calculate the position, orientation and velocity vector of a vessel without the need for external references. The same system is also deployed in aircraft and missiles. As a result, the company says its pitch, roll and yaw stabilization accuracy is better than 0.1 degrees.

The company's smallest offering is the USAT 24 (Ultra Small Aperture Terminal), with an antenna size of 24 inches (60 cm). It was designed specifically for the leisure market for vessels staying close inshore (where signals are stronger). It weighs in at 100 pounds (45 kg) and retails for about $28,500 (not including the modem, which will add about $8,000 to the price).

Sea Tel's 10-series of Ku-band VSAT antennas is suitable for vessels of about 100 feet and up. Their new 4010 model has a 1 meter antenna and weighs 250 pounds (116 kg). Its three-axis stabilization system is said to respond to ships movement at a rate as fast as 90 degrees per second and is configured for transmission rates of up to 1 mbps for shore-to-ship data transfer and up to 256 kbps for ship-to-shore (though again this is more dependent on the airtime supplier than the hardware). The system starts at $45,500.

KVH Industries: The Middletown, RI-based company's TracPhone product line gives boaters several options for satellite communications. It's mini-VSAT broadband network and compatible TracPhone systems offer bundled hardware and worldwide airtime service. In addition, KVH sells Inmarsat-compatible Fleet and FleetBroadband hardware and airtime under the TracPhone trademark. The company's satellite television products are branded under the TracVision name.

KVH is unique in that it not only manufactures VSAT antennas with integrated modems, but also owns and manages a global mini-VSAT broadband network, which is carried by nine Ku-band satellites around the globe. This means that its hardware and airtime packages can be used worldwide without changes to the software or hardware (i.e. modems). This also means that there is a single point of contact for customers for both their hardware and software. If there are problems with either, technicians can dial into the customer's equipment and perform complete diagnostics and troubleshooting remotely.

KVH owns and maintains hubs within each of the 10 ground stations (teleports) its satellites use around the world. This gives them control over the quality of the network connections. When a user transitions from one area to another, the system automatically tracks a new satellite without user intervention.

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In the case of voice transmissions being sent to regular telephones, they are sent as VoIP transmissions, but after arriving at the earth station hub, the VoIP signals are routed to a publically switched telephone network. When communicating with another ship or computer, the voice data is both sent and received as VoIP.

Downsides of Satellite Communications

Of course, no technology is flawless, including satellites. To some extent, satellite communications can be slowed by monsoon-type rains or wet, heavy snow along the path of transmission, but generally they are not affected by weather. Ice on the dish can interfere with communications, but where ice is a factor antennas are fitted with small heaters. The higher the band, the more it is affected by weather.

Because geostationary satellites are located above the equator, they can't "see" the north or south polar regions, so VSAT coverage is limited or non-existent in those areas above or below 70 degrees latitude. High fiords (such as some of the inlets on the west coast of Canada and Alaska) and heavy forest cover can also interfere with communications as they can block the direct line of sight needed between the overhead satellite and the antenna dish.

The other downside to VSAT is the relatively high cost of the hardware ($17,000 to $50,000 or more).

Voice and Data Transmission Speeds

In the past, one of the limiting factors to satellite Internet was painfully slow transmission rates (far less than dial-up). However, much has changed and today's VSATs offer speeds that can match many home Internet data speeds. As with all broadband Internet services, satellite Internet has been configured to give priority to downloading (shore-to-ship) over upload speeds (ship-to-shore) because downloading is the most common function.

With VSAT (and terrestrial Internet), the speed at which data is transmitted is dependent more on the user's specific airtime plan and choice of network than the hardware to which it is connected (though generally, larger antennas are capable of faster speeds). At its slowest, VSAT airtime suppliers offer ship-to-shore (upload/upstream) and shore-to-ship (download/downstream) speeds of 64 kbps. This is only a little faster than standard phone-based dial-up (56 kbps). The fastest speeds are currently about 4 Mbps, which is comparable to the better cable or phone-based DSL connections. And as is the case with regular Internet, customers pay higher rates for faster speeds and/or more data capacity. Whether on land or at sea, when airtime providers use the term "speeds of up to X mbps" those speeds are rarely achieved due to the shared nature of the networks. Streaming services are available from many providers for applications such as broadcasting and videoconferencing, but they tend to be expensive.

Airtime Costs

KVH is the only end-to-end hardware manufacturer that has also built its own global service network and sells bundled airtime packages. Sea Tel's and Intellian's antenna hardware must be configured to work with modems from iDirect, Hughes or Comtech. There are many companies throughout the world offering compatible satellite airtime plans, but the modem needs to be matched up to the service provider's network. The choice of which provider to use is based on the vessel's location and area of operations and its data and voice needs.

Airtime providers require the purchase of a specialized modem compatible with their carrier. This works well if the boat is operating exclusively in a region covered by that airtime provider, but if the boat is cruising the world, a number of different airtime providers may be required and each one will need a modem specific to that provider and possibly changes to the antenna hardware or software. KVH's airtime plans (they lease transponder space directly from the satellite owners) are designed to use the same modem regardless of where in the world the vessel is travelling.

Airtime providers typically offer both fixed monthly plans that include unlimited airtime (to a point) or volume-based plans based on megabits needed/used each month, which may or may not include VoIP service.

KVH's new V3 model VSAT hardware/airtime package offers Internet access and e-mail at data rates of 128 Kbps (ship-to-shore) and 2 Mbps (shore-to-ship) for $0.99 per MB and $0.49 per minute for voice calls anywhere in the world. Fixed plans for their mini-VSAT (V7) start at about $995 per month with upload and download speeds of 64 kbps. This includes unlimited Internet (to a point), emails and phone. Their top-end fixed VSAT plan offers 512 kbps upload and 2 mbps download speeds for $5,270 per month.

While these are just examples, each airtime provider has its own rate schedule and they can vary greatly, but be sure to read the fine print. If the boat is only going to be used for a few months of the year, ask about seasonal rates. Most contracts are based on yearly plans. This is an important factor and it can have a big impact on the annual cost of airtime.

For voice calls, most airtime providers charge for long distance between the point where the call enters the public telephone switching system and the destination telephone. In North America, most owners will opt for a North American phone number for their VoIP communications to minimize long-distance charges.

Frequencies

Satellites receive and transmit information within the microwave band from 1 to 40 GHz. This part of the radio spectrum is best suited for satellites, because signals are not deflected by the earth's atmosphere like lower frequency FM, VHF and UHF radio waves (40 to 1,000 MHz). Inmarsat, Iridium and Globalstar transmit in the L-band (1 to 2 GHz) while VSAT uses C-band, Ku-band and most recently Ka-Band.

C-band (4 to 8 GHz) was the original band used by the communications satellite industry. It has a wider beam than Ku-band and requires higher transmit power. Antennas are usually more than 6 feet in diameter, which is necessary to capture more of the widely dispersed signal. Data transmission speeds are relatively slow compared to Ku-band. C-band is still in widespread use (primarily with low-earth-orbit satellites and for Fleet Broadband. It is also less affected by weather than the Ku and higher Ka-bands. C-band is also the frequency used for terrestrial mobile phone systems and concerns have been raised about potential interference between satellite users and cellphone users as worldwide cellular networks expand.

Ku-band (12 to 18 GHz) is the most common for satellite TV and communications in North America and Europe. It uses a higher frequency than C-band, which means that smaller antennas can be used. Ku-band satellites broadcast a very narrow beam with lots of power. This means data transfer speeds are faster. Ku-band antennas must be pointed precisely at the satellite (within about a degree or two) for proper reception.

Ku-band is configured to focus over spe-

cific geographic areas. For example, one beam could cover the whole of Australia, another the Caribbean and several for North America. Satellite owners can dial the power up or down and adjust the width of a satellite beam depending on the traffic in a given geographic area. As well, in areas of heavy rain (Florida, for example) the power can be increased to better penetrate, while in dry areas such as Mexico, less power is required.

Ka-band (27 to 40 GHz) is similar to Ku-band, but will have double the data capacity/speeds of Ku-band. Several regional Ka-band services are either available or announced, and Inmarsat has begun building a new global Ka-band service, which should be completed in 2014.

The Future

The most exciting news for the industry is Inmarsat's Global Xpress VSAT network. Inmarsat provides global mobile satellite communications (airtime). Although the company already operates 11 satellites in geostationary orbit, the services they have traditionally offered, on L-band, and the technology they use were designed primarily for data speeds of less than 1 mpbs.

Global Xpress will incorporate three geostationary satellites, called Inmarsat 5, which are expected to be operational in 2014. Inmarsat is promising broadband speeds of twice that of anything available today. The new system will utilize the extremely high frequency Ka-band, which is already in use for satellite TV broadcasts. Inmarsat will be the first company to utilize the Ka-band for global coverage and integrated commercial satellite communications.

The Ka-band uses a narrower beam than Ku-band and is more powerful. Ka-band offers higher bandwidth rates, which the company says will translate to lower cost airtime. The company says the system will be able to utilize dishes as small as 15 inches and predicts the Ka-band will become the band of choice in the coming years.

Hardware and airtime costs will continue to be a major factor for recreational boaters. Expect to see smaller antennas costing less than larger antennas and an increase in functionality across the board. In other words, you'll get more for your money, but it won't cost much less.

According to Jim Dodez, vice president of marketing and strategic development for KVH, "Just like on land, people have an insatiable desire for increased connectivity. People are so used to being on line for uploading files, using Facebook, sending email and dialing into the office. They want to be able to do this not only to stay in touch with family and friends, but also to run their businesses from their boats. Owners of small yachts have demanded that satellite communications costs be brought down to earth, and we're doing just that."

As for industry growth, Atul Chawla, product marketing manager for Sea Tel, said, "I expect this market to have good growth ahead as the need for communications continues to increase and new innovative products are launched."

According to industry analyst Northern Sky Research, the maritime broadband business is expected to grow from its current level of about $800-900 million to $2 billion over the next few years.

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About the author

Peter A. Robson is the former editor of Pacific Yachting *magazine. He is a veteran sailor whose most recent offshore adventure was crewing on the winning boat during the 5,600-mile, non-stop, China to Victoria, Canada leg of the Clipper Round the World Yacht Race. He currently writes about everything marine—with an emphasis on technical articles—for boating magazines around the world.*