# Airborne Antenna Systems for DVB-RCS Solutions

*Dimov Stojce Ilcev (ilcev@dut.ac.za) – Durban University of Technology (DUT), Durban, South Africa*

**Abstract:** This paper introduces development and implementation of new Airborne Satellite Antenna (ASA) used for Very Small Aperture Terminal (VSAT) of Aeronautical Satellite Broadband System (ASBS) known as a Digital Video Broadcasting-Return Channel via Satellite (DVB-RCS). Directional High Gain Antenna (HGA) of ASA system usually needs to be protected by special radome and always positioned in the focus of satellite by a special antenna mechanical and electrical antenna tracking mechanism situated on the special stabilized pedestal. The several possible types of broadband ASA via different Radio Frequency (RF) band, such as Ku-band transceiving, airborne satellite broadband antenna, L and Ku-band antennas for DVB-RCS and Internet Protocol Television (IPTV) solutions, Ka-band transceiving antenna system for DVB-RCS solutions, Antenna Systems for Aeronautical Satellite Broadcasting (ASB) are discussed.

**Key Words:** DVB-RCS, ASA, VSAT, HGA, ASB, RF, IPTV, FSC, MSC, GEO, LEO, VDVoIP, TVRO

## 1. Introduction of Airborne Antenna Systems for DVB-RCS Solutions

The DVB-RCS satellite technology is developed more than two decades ago and is taking big role in Fixed Satellite Communication (FSC) and more recently is using in all forms of Mobile Satellite Communication (MSC) applications. The mobile VSAT service provides via Ground Earth Stations (GES) to users broadcast, broadband, multimedia and very fast Internet with IPTV and ABS over Geostationary Earth Orbit (GEO) satellites using different onboard antenna solutions.

The DVB-RCS avionics antenna can serve just for transceiving facilities of DVB-RCS voice, data and video signals and DVB TV transmissions or can be integrated with IPTV reception. Recently Non-GEO mobile and personal communication systems such as Iridium and Globalstar deployed DVB data transmissions via own Low Earth Orbit (LEO) satellites. In general the new service of DVB-RCS has to provide Voice, Data and Video over IP (VDVoIP) via two way DVB-RCS VSAT transceiving antenna systems. There is possibility also to install aircraft antenna just for receiving of TV program known as Television Receive Only (TVRO) or even for IPTV **[1, 2, 3]**.

## 2. Fixed and Mobile Interactive DVB-RCS Terminals

The satellite DVB-RCS system or VSAT station, both fixed and mobile, is made of two separate sets of equipment: the Outdoor Unit (ODU) and the Indoor Unit (IDU). The outdoor unit is the VSAT interface to the satellite, while the IDU is the interface to the customer's terminals or LAN.

**1. Outdoor Unit (ODU)** – In **Figure 1** is shown a diagram of an ODU, with its antenna and the electronics package containing the transmitting amplifier, the low-noise receiver (Rx), the up and down-converters and the frequency synthesizer. For a proper specification of the ODU or satellite antenna equipment, as an interface to the satellite, the following parameters are of importance:

- The transmit and receive frequency bands;

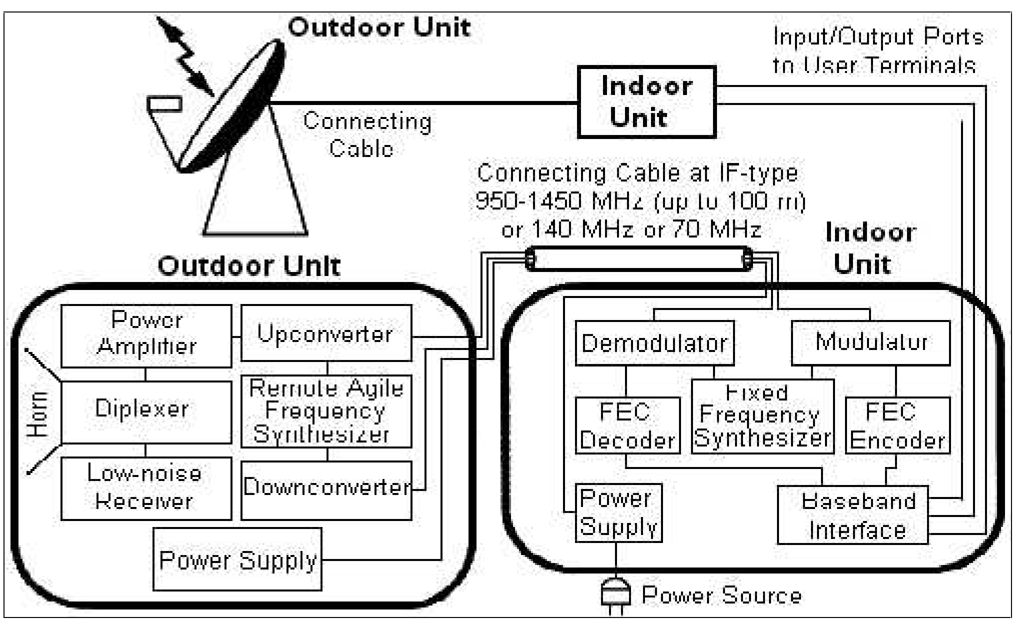


**Figure 1.** VSAT Outdoor and Indoor Units – Courtesy of Book: by Maral **[1]**

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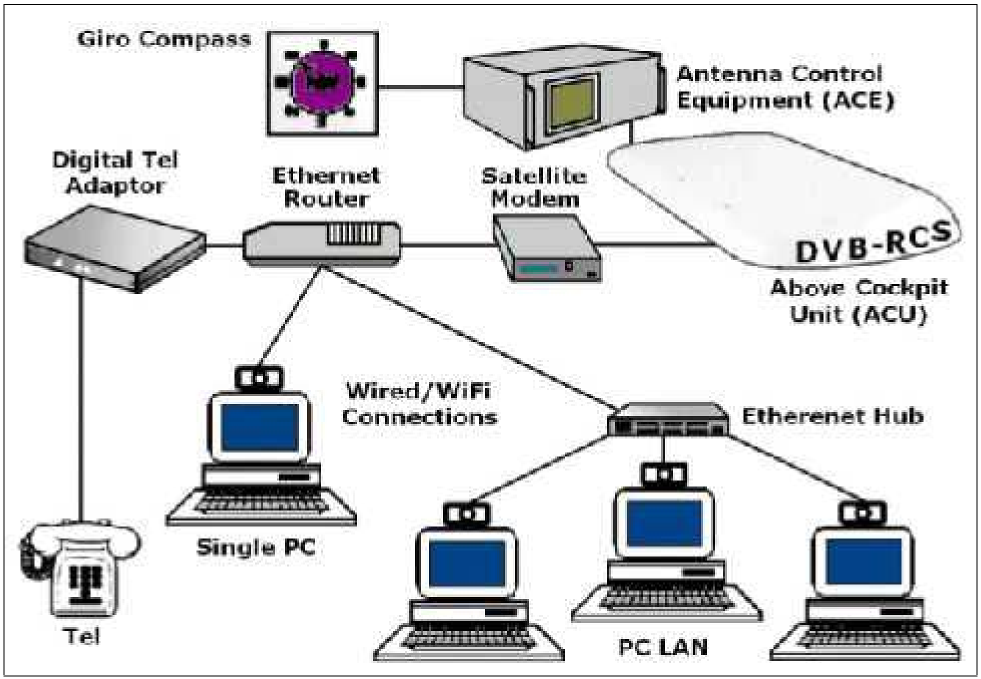

**Figure 2.** Aeronautical DVB-RCS Outdoor and Indoor Units – Courtesy of Paper: by Ilcev **[2]**

- The transmit and receive step size for adjusting the frequency of the transmitted signal carrier or for tuning to the received carrier frequency;
- The EIRP value, which is presented to determine the performance of the radio frequency uplink. The EIRP depends on the value of the antenna gain, and hence its size and transmit frequency, and on the transmitting amplifier output power;
- The figure of merit G/T, which determines the performance of the RF downlink. Thus, the G/T radio depends on the value of the antenna gain, and hence its size and receive frequency, and on the noise temperature of the receiver; and
- The antenna sidelobe gain variation with off-axis angle, which controls the off-axis EIRP, and G/T, hence determining the levels of produced and received interference.

Operating temperature range, wind loading under operational and survival conditions; rain and humidity are also to be considered. The ODU can be installed on the roof, mast or onboard mobiles, such as aircraft, and may provide to Indoor Unit (IDU) the following features:

– Full DVB-RCS compliance and easy to install with range of C, Ku or Ka-band antenna sizes possible for optimizing system throughput from 0.75 - 2.4 m.

**-** Standard ODU interfaces full compatibility with any DVB-RCS or VSAT satellite modem with two-way enhanced Digital Satellite Equipment Control (DiSeqC) capability, which interfaces all units between IDU and satellite transmitter (Tx) supporting automatic line-up function.

At this point, by using special mobile satellite tracking antennas, VSAT can be installed onboard mobiles, such as ships, road and railway vehicles, and aircraft. In **Figure 2** are shown Aeronautical DVB-RCS VSAT Outdoor and Indoor Units. The Above Cockpit Unit (ACU) or satellite antenna is autotracking by using Gyrocompass and Antenna Control Equipment (ACE) and can be installed on aircraft fuselage.

Compared to alternative solutions aircraft antenna can provide a data rate that reaches speeds up to 25 Mb/s upload and up to 150 Mb/s download. In the proper manner, aircraft VSAT antenna, shown as ACU in **Figure 2** is illustrated high-grade motorized satellite antenna, which is an ideal for voice, video and data connectivity or audio/video transmissions. With a simple push of a button, the aircraft VSAT antenna dish will be locked onto predetermined GEO satellite and will start with transmitting and receiving the content in less than minute after tuning up to the satellite. Any VSAT mobile and portable autotracking satellite antenna is focused onto the corresponding satellite almost in the real time.

**2. Indoor Unit (IDU)** – The IDU installed at the user's facility is shown in **Figure 1,** while aircraft IDU or Below Cockpit Unit (BCU) is shown in **Figure 2.** In order to connect his terminals to the VSAT, the user must access the ports installed on the rear panel of the outdoor unit. In **Figure 1** is shown a diagram of an IDU, with its electronics package containing the modulator, demodulator, FEC decoder and FEC encoder, RF synthesizer, baseband interface and power supply. Thus, for a proper specification of the IDU, as an interface to the user's terminals or to an LAN, the following parameters are of importance **[1, 2, 4, 5]:**

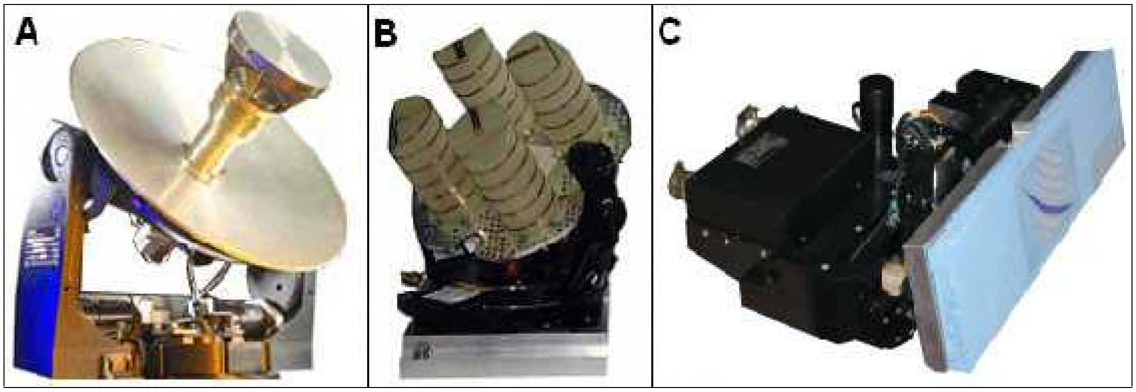


**Figure 3.** Aeronautical DVB-RCS VSAT Outdoor Units – Courtesy of Brochures: by Orbit **[6]**

- Number and type of ports, such as mechanical, electrical, functional and procedural interface, often specified by reference to a certain standard.
- Port speed is the maximum bit rate at which data can be exchanged between the user terminal and the VSAT indoor unit on a given port. The actual data rate can be lower. Coherent modulation schemes such as BPSK or QPSK are used. For acceptable unit performance, transmission rate should be higher than 2.4 $Kb/s^{-1}$, otherwise phase noises becomes a problem. For lower data rate PSK is avoided and FSK is used instead.

The IDU terminal can be installed in rural and urban office or with some modification onboard all mobiles including aircraft. Mobile terminals provide two-way Multimedia IP communications via adequate GEO satellite at C/L, Ku or K-band frequencies, for Maritime, Land and Aeronautical mobile applications. The main parts of BCU or DVB transceiver shown in **Figure 2** are Ethernet Router and Satellite Modem, which are usually integrated in one unit known as a Router. The additional onboard equipment connected to the Ethernet Router are a Digital Tel Adaptor, which is connecting Tel sets, and Ethernet Hub, which is connecting a number of PC, IPTV, VoIP sets and VDVoIP facilities in onboard aircraft LAN.

The mobile IDU terminals can be supplied for either desktop or rack mounting onboard ships, buses, trains or aircraft and comes in a scalable choice of performance with a variety range of data IP throughputs up to 35 Mb/s or more. This unit can serve for government (military applications), state corporations, institutions, private companies or home offices offering an open-interface for high-capacity broadband access that bypasses the "last mile" bottleneck associated with terrestrial infrastructure. It offers broadcast, broadband and multimedia access to core IP ground networks using standard technologies such as DVB-S, IP interfacing DVB-T and MPEG/DVB-S or DVB-S2 with user terminals via corresponding C, Ku or Ka-band transponder. The IDU units are capable to provide RLS service up to 100 PC terminals in LAN sets simultaneously with Ethernet interface or, let's say PC and IPTV units.

### 3. Airborne Ku and X-band Transceiving Antenna System for DVB-RCS Solutions

The demand for making flights more productive, safe, cost effective and pleasant for passengers is one of the winning factors for airlines in today's business community. Current trends point towards high data rate satellite communication services deploying Internet applications in particular. In an aeronautical scenario, global coverage including poles is essential for providing continuous service. Satellite communication becomes indispensable and with the demands for increasing data rate requirements they need implementation of modern airborne antenna systems transmission.

Aeronautical communication systems are growing very fast after deployment of satellite DVB-RCS broadband, Aeronautical Satellite Broadcasting (ASB), TVRO, IPTV and systems. These systems have very strong demands for development very sophisticated airborne satellite tracking antennas. Therefore, novel avionics communication systems are required for various purposes, for example to increase the flight safety and operational integrity as well as to enhance the quality of service to passengers onboard. To serve these purposes, a key technology that is essential to be developed is an antenna L, X, Ku and Ka-band system that can provide broadband connectivity within aircraft cabins at an affordable price **[1, 2, 3, 4].**

### 3.1. Orbit Communication Antenna Systems

The Israel Orbit Technology Group has designed different aeronautical satellite antennas, azimuth positioners and controllers.

**1. Airborne Ku-band AL-1614 Tx/Rx Antenna** – This is avionics DVB-RCS antenna based upon a proven concept implemented on various Orbit applications and used over the last 15 years, shown in **Figure 3 (A)**.

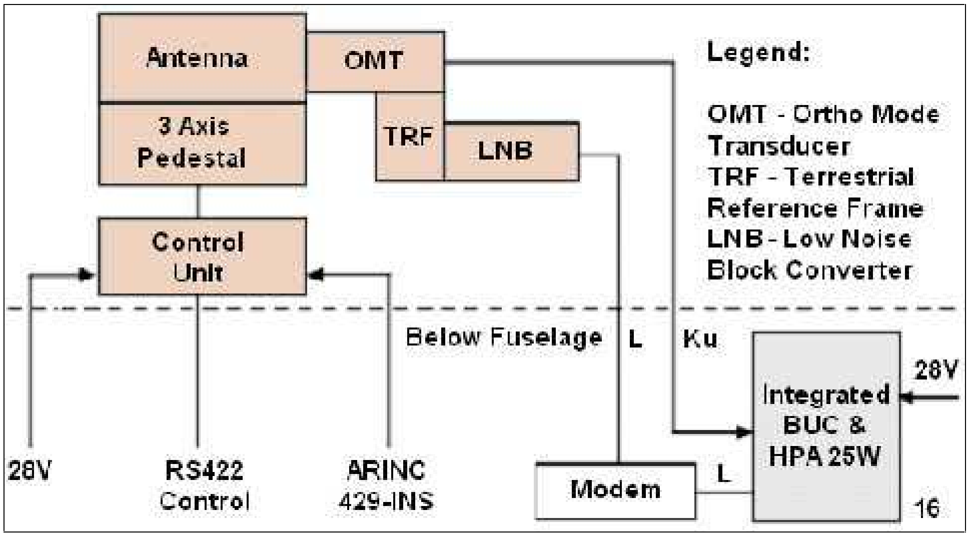


**Figure 4.** System Layout of Ku-band AL-1614 Antenna – Courtesy of Brochures: by Orbit **[6]**

This airborne antenna is based on modular sub-assemblies such as: ACE, Gear/Motor/Encoder Assembly and RF Front End, which are tested and proven to meet necessary airborne environmental conditions.

It provides access to satellite broadband networks anywhere, anytime under any weather condition while passengers are in the air, and has become essential. It is latest innovative stabilized VSAT Ku-band antenna solution. Comprising a compact yet efficient dual reflector antenna with an RF front end delivering optimal nonstop quality connectivity with the selected satellite.

The components of this antenna are assembled and integrated for this specific application in order to meet the required compact system design of Airborne Ku-band AL-1614 Tx/Rx Antenna, which System Layout of aircraft above and below fuselage is shown in **Figure 4.**

The antenna unit complies with ARINC, ETSI and FCC satellite regulations and provides the following key benefits and features: it is efficient “Dual Reflector” of antenna system, high EIRP of > 44 dBW, G/T is >9.5dB/°K and the minimum dynamic tracking error meets aeronautic standard RTCA 160D, provides the typical data rate of 3 Mb/s in reception and 512 KB/s in transmission, typical Eb/No is 6dB and RF bands of antenna are for Tx 14.00 - 14.50 GHz and for Rx 10.95 to 12.75 GHz.

**2. Airborne X and Ku-band Tracking Antenna Positioner AL-1610-1E EL/AZ –** This is multiband airborne tracking antenna system for air to ground data-link on an aircraft, in order to provide 360º coverage over GEO satellites. The system incorporates two antennas per aircraft, one of which is mounted in the tail-cone and the other in the forward belly radome, shown in **Figure 3 (B).** The antenna is a parabolic 10” dish with a vertically polarized feed for 10.70 to 11.70 GHz frequency range and with maximal elevation and azimuth angles. The AL-1610-1E is controlled by AL-1610-3E Airborne Controller.

**3. Airborne MM Wave Ku-band AL-1615-1 Tx/Rx Antenna** – This is airborne tracking antenna system for communication with the ground subscribers and users via GEO satellite, shown in Figure 3 (C). The positioner of this unit supports a flat plate antenna, uniquely designed to require minimal radome volume. The control system tracks an GEO satellite in focus while subjected to the aircraft’s dynamic movement. This airborne satellite antenna is controlled by AL-1610-3E airborne controller **[6].**

### 3. 2. QEST Antennas for DVB-RCS and IPTV Solutions

On “Aircraft Interiors Expo” held on 1-3 April 2008, in Hamburg, the German antenna company Quantenelektronische Systems GmbH known as QEST Systems announces the development of a modern bi-directional aeronautical antenna for satellite communications in Ku band range. This small and lightweight high performance antenna will enable broadband applications for passengers aboard of aircraft, such as fully-fledged Internet access, E-mail, video conferences and access to corporate networks including attachments as well as simultaneous live TV reception.

However, for a full global usage of such mobile communications satellite systems today are used in two RF bands: L-band (1.5 - 1.7 GHz) and Ku-band (10.7 - 14.5 GHz). Due to physical and system related reasons; possible data rates in L-band are much smaller than in Ku-band. In future, the usage of L band only will not be sufficient to supply enough bandwidth for many passengers using broadband applications at the same time (e.g. aboard of larger passenger aircraft).

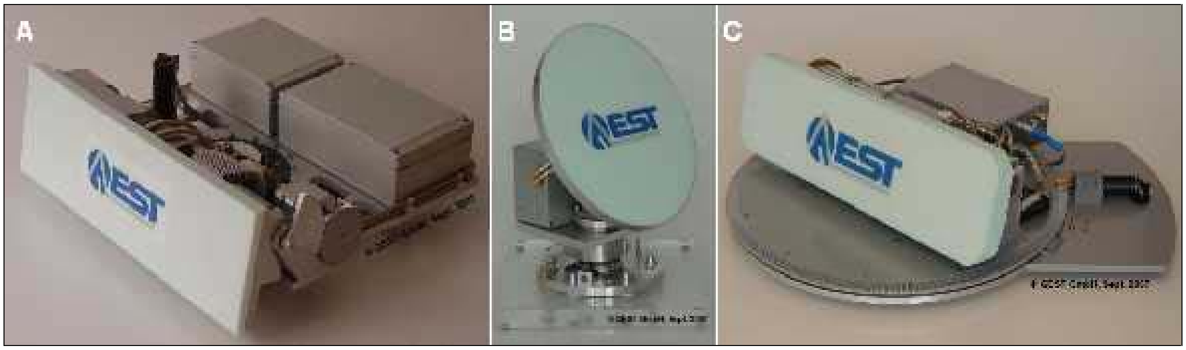

**Figure 5.** Dual Band DVB-RCS Transceiving and Receiving Antennas – Courtesy of Brochures: by QEST **[7]**

**1. Fuselage Mount Dual Band L and Ku-band Airborne Broadband Transceiving Antenna –** The modern antenna design of the German QEST Company is ultra-small bi-directional La and Ku-band antenna, illustrated in **Figure (A)**. Thus, with its multi-layer primary array aperture this high end product simultaneously covers Ku-band Rx for fast downlink of large data quantities to the aircraft as well as L-band Rx/Tx services as uplink channel and supplementary or fallback downlink channel in one integrated antenna. These results in numerous benefits, such as smallest size, lightweight, two antennas, including related services in one, physical shape without size increase, multi-satellite operations and very low service and lifecycle cost.
Antenna enables radically new service providing concepts: by combining Ku and L-band, a novel, hybrid data link can be established. In fact, Ku-band is used for a fast downlink of large data quantities over DVB-S and DVB-S2 quality to the aircraft, whereas L-band serves as uplink channel and supplementary or fallback downlink channel with attractive bandwidth at affordable cost. Thus, this result in unprecedented connectivity options and maximum flexibility for airline owners and operators: combination of cost efficient Ku-band downlink with globally available and reliable RF at L-band connectivity.
Therefore, asymmetric aircraft data link perform high volume downlink combined with reasonable and affordable data rates in uplink, which will provide avoidance of proprietary and expensive Ku-band uplink. This aircraft antenna is a real future-proof and secures connectivity hardware investments, as it eliminates dependency of a proprietary Ku-band satellite service provider or signal-encoding scheme.
The Ku-band frequency range is between 10.70 and 12.75 GHz, antenna gain is 29.5 dBi, antenna G/T is >13 dB/K, transfer of data rates are up to 40 Mb/s per transponder of Rx, more than 100 transponders covers simultaneously and elevation coverage is 90° to 0°, providing full performance for all satellite elevation angles and regular flight maneuvers, and including simultaneous Ku-band (Rx) and L-band (Tx + Rx) operation (multi-frequency and multi-satellite operation).
The L-Band frequency range is 1.50 - 1.70 GHz, thus antenna gain and G/T complies with aircraft SwiftBroadband of Inmarsat specifications. Data rates have SwiftBroadband capacity of 432 Kb/s per channel in Tx and Rx satellite multi channel use. Satellite elevation coverage is from 90° to 0° (full performance for all elevation angles and regular flight maneuvers) including simultaneous Ku-band (Rx) and L-band (Tx + Rx) operation (multi-frequency and multi-satellite operation). The diameter of this antenna is 25.2 inches (64 cm), height is 5.7 in (14,5 cm) and weight is approximately 33 lbs (15 kg).
**2. Tail Mount Dual Band Airborne Broadband Transceiving Antenna –** The specific design of the QEST Company is extremely small reflector bi-directional Ku-band satellite antenna, shown in **Figure (B)**. The diameter of this antenna is 11 inches (28 cm), height is 13 in (33 cm) and weight is approximately 22 lbs (10 kg).
**3. Fuselage Mount Dual Band Airborne Broadband Receiving Antenna –** The modern design of the QEST Company is ultra-small bi-directional Ku-band antenna, shown in **Figure 5 (C)**. It is designed for efficient reception of large data downlink volumes and for high performance airborne Direct Broadcasting Satellite (DBS)/Live TV receiving system.
Based on similar core avionics satellite antenna technologies it offers comparable benefits to the airlines owners and operators such as ultra-small size, lightweight superior performance, efficient reception of high volume DBS/Live TV (DSS, DVB-S, DVB-S2 up to HDTV quality) and low lifecycle cost. The dimensions of this antenna are in diameter 15.7 in (40 cm), height: 3.9 in (10 cm) and weight (approx.): 26.5 lbs (12 kg).
Antenna has Ku-Band frequency range of 10.70 - 12.75 GHz, antenna gain is 27.5 dBi, antenna G/T: is >11 dB/K, data rates are up to 40 Mb/s per transponder Rx with more than 100 transponders (> 500 TV channels) simultaneously and elevation coverage is 90° to 0° (full performance for all elevation angles and regular flight maneuvers).

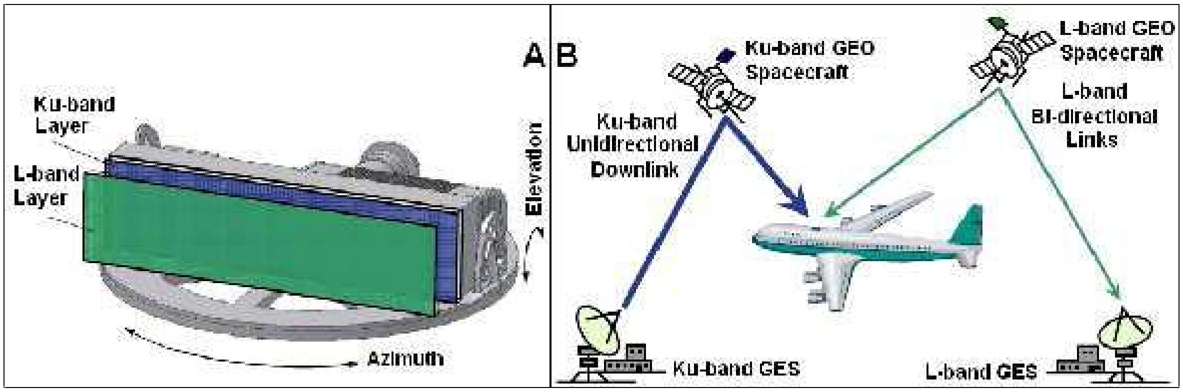

**Figure 6.** Dual Band Transceiving Antennas and Multiband GEO System – Courtesy of Brochures: by QEST **[7]**

**- Characteristics of Dual RF Band Airborne Antenna and Multiband GEO System –** As stated earlier, the multi-layer primary aperture QEST antenna simultaneously covers Ku band (receive) as well as L band (receive and transmit) services in one integrated antenna. This solution results in numerous benefits as follows: smallest size, lightweight, two antennas (incl. related services) in one physical shape without size increase, multi-satellite operations, low service and lifecycle cost. Namely, the dual band airborne broadband antenna enables cost effective solution and radically new service providing concepts: by combining Ku and L-band, a novel, hybrid data link can be established. In such a way, Ku-band is used for a fast downlink of large data quantities to the aircraft, whereas L-band serves as uplink channel and supplementary or fallback downlink channel. The special QEST technical solution is design of multilayer aperture for multiband antenna operations, shown in **Figure 6 (A).** The QEST proposal of dual band airborne broadband antenna covers Ku-band as well as L- band service simultaneously in one small antenna is shown in **Figure 6 (B).**

Accordingly, the summary of dual band airborne antenna system designs of both Ku and L-band satellite services have their specific advantages and disadvantage that appear to be diametrically opposed to each other. Advantages of Ku-band are large bandwidth and cheap downlink. Disadvantages are that uplink transmission is complex and expensive (valid for the aeronautical antenna technology as well as for the satellite infrastructure), and that coverage is limited beyond the large landmasses, but with compromised performance. Advantages of L-band are global coverage and affordable uplink, while disadvantage is smaller bandwidth **[7]**.

### 3.3. Aircraft Multiband Transceiving (Tx/Rx) Antennas for Broadband Solutions

Satcom-On-The-Move (SOTM) airborne antenna products of the General Dynamics share a legacy of proven technical performance and availability to maintain the data link during dynamic platform motion for VDVoIP aeronautical onboard service in cockpit and cabins. In this sense, these aircraft antenna products provide reliable "on satellite" tracking accuracy via combination of onboard aircraft integral tracking Rx, gyro stabilization, and inertial measurement unit including Attitude and Heading Reference System (AHRS).

**1. Multiband Airborne Antenna Model 13-13A –** The Model 13-13A series terminals provide high data rate at X, Ku or Ka-band (High and Low band SOTM) over a wide range of operational conditions, and can be ordered with an AHRS, shown in **Figure 17 (A).**

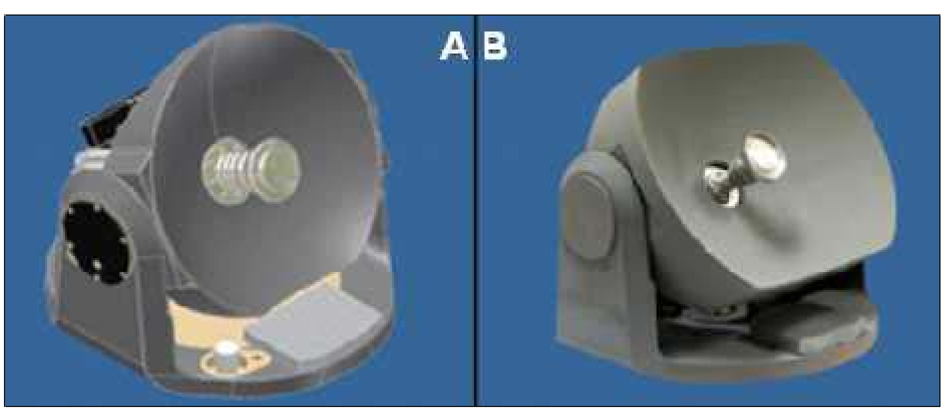

**Figure 7.** Multi-band Aircraft Tx/ Rx Satellite Antennas – Courtesy of Brochure: by SOTM **[8]**

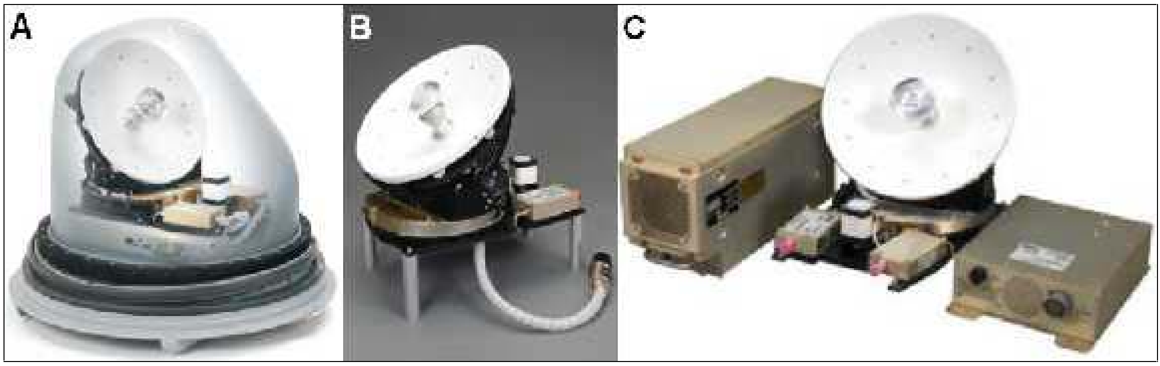

**Figure 8.** Dual-band Aircraft TX and Rx Satellite Antennas – Courtesy of Brochure: by ViaSat **[9]**

This antenna is lightweight low profile design and with all RF components on elevation payload for high efficiency RF Tx and Rx. Antenna includes the antenna positioner, servo electronics, tracking receiver, block up and down-converters and high efficiency solid state power amplifier, which are contained on the stabilized pedestal interfaced to input power, Ethernet and L-Band Tx/Rx modem.

**2. Multi-band Airborne Antenna Model 13-17LPA –** This terminal uses the same RF band and provides the same performances and features as previous model, shown in **Figure 7 (B) [8]**.

### 3.4. Airborne Ku/Ka-band Transceiving Antennas for Broadband Solutions

To reach level of high efficiency ViaSat designed two exclusive ArcLight technologies: Code Reuse Multiple Access (CRMA) and Asymmetric Paired Carrier Multiple Access (A-PCMA), which enable data transmissions coming back to the GES (hub) from remote site antennas to be combined within the same bandwidth as the outbound channel. The ArcLight system incorporated the space segment of Yonder GEO satellites to transfer broadband content from aircraft to the ground and vice versa via the following antenna systems:

**1. ViaSat Hatch-Mount Airborne Antenna VMT-1220HM –** This antenna provides two-way airborne broadband via Ku/Ka-band broadcast-on-the-move for large aircraft missions worldwide, which delivers high-speed IP communications via ViaSat Yonder GEO satellite network, shown in **Figure 1 (A).** The Yonder mobile broadband can send live, full-motion high-definition video over the horizon, make phone calls, conduct video conferences, access classified networks, and perform mission-critical communications while in flight. Equipped with integrated technologies and robust waveforms, this antenna terminal has proven in-theater to deliver streaming data rates up to 10 Mb/s and for shared forward link from 10 to 30 Mb/s. The antenna is transmitting at Ku-band from 14.00 to 14.50 GHz and receiving from 11.55 to 12.75 GHz. The same antenna is able to transmit at Ka-band from 29.5 to 31.00 GHz and receiving from 19.70 to 21.20 GHz. This antenna is a parabolic 12" satellite dish providing maximal elevation angles from 5° to 85° and azimuth angles up to 360°.

**3. ViaSat Helicopter Antenna VMT-1220HE –** This antenna is dedicated for mounting onboard helicopters and has the same technical design and operational characteristics as previous, shown in **Figure 8 (B).**

**3. ViaSat Light Aircraft Antenna 1220 –** This is small footprint high data rate antenna for installation onboard light aircraft (VMT-1220LA) is a complete Ku/Ka-band airborne terminal with an ultra small 12-inch antenna and lightweight cockpit equipment delivering the same broadband IP communications over the horizon as previous terminals, presented in **Figure 8 (C).** This aircraft antenna is providing the same streaming data rates of forward and return satellite links up to 10 Mb/s via the same transmitting and receiving operating frequencies **[9]**.

## 4. Antennas for Aeronautical TV Broadcasting

Satellite broadcasting at the 12 GHz of Ku-band stream has become more widespread and the need for TV reception by relatively large and medium size aircraft. This service is very attractive for both commercial and military applications including for intertwinement of passengers in flight. The special digital TV and audio content distributed by satellites is becoming the standard for TV reception onboard aircraft worldwide. Since a satellite communication system covers a wide area of service, it is inherently suitable for mobile reception of two new services known as Direct Audio Broadcasting (DAB) and Direct Broadcasting Satellite (DBS) in propagation conditions compared to its terrestrial TV satellite broadcast counterparts because the former suffers less interference due to multipath propagation as commonly experienced in practice. Thus, the TV satellite broadcasting service is deploying the following airborne satellite antenna systems:

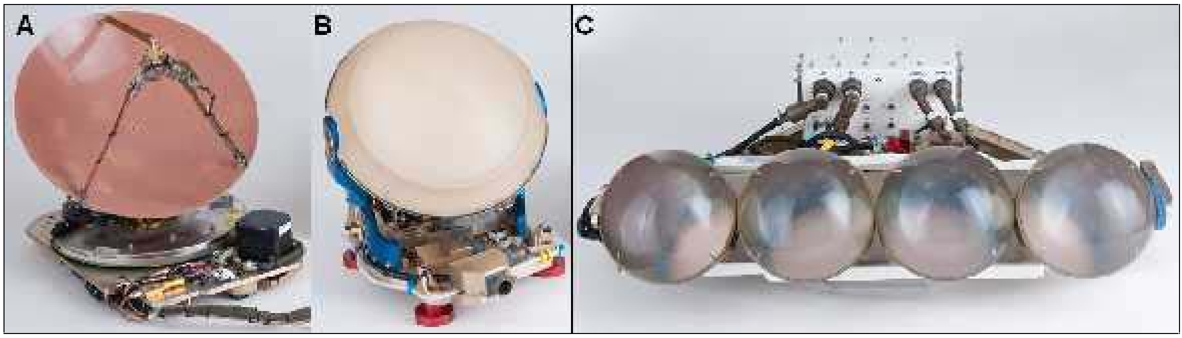

**Figure 9.** Tailwind Multiregion In-flight TV System – Courtesy of Brochure: by Rockwell Collins **[10]**

**1. Tailwind 300 Multiregion In-flight TV System –** This is the Rockwell Collins Airborne TV ARINC fully integrated system that enables private aircraft to receive Ku-Band DBS TV signals onboard aircraft and access the full spectrum of digital video and audio programming available from DBS satellites, which antenna is shown in Figure 9 (A). The system takes these signals automatically, decodes them to the correct broadcast format and then distributes them to the aircraft onboard audio-video or entertainment management systems for passengers in flight.

**2. Tailwind 500 Multiregion In-flight TV System** – This is the similar Ku-band ARINC antenna system for the executive jet aircraft, offers the kind of content-rich live programming from DBS satellites that allows you to stay informed and be entertained while flying, which antenna in radome is shown in **Figure 9 (B).**

**3. Tailwind 550 Multiregion In-flight TV System** – This robust airborne fuselage mount multi-region in-flight TV antenna system provides passengers in flight informed and entertained, shown in **Figure 9 (C).** The Tailwind 550 is a fully integrated system that enables private aircraft to receive Ku-band DBS TV signals, providing access to the full spectrum of digital video and audio programming currently available from DBS satellites. This airborne broadband antennas can be configured for multiple flight zones throughout the passenger cabins and with combinations of up to 32 unique programming receivers providing flexibility to choose both personalized content and viewing location **[10]**.

## 5. Conclusion

The aircraft antenna configuration needs to be compact and lightweight. These requirements is difficult to achieve because the compact antenna has major disadvantages such as low gain and wide beam coverage, while directional antenna has quite heavy components. However, a new generation of powerful satellites with high EIRP and G/T performances should permit the design of compact and lightweight antennas.

New physical shapes of antennas and less weight are very important requirements in connection with compactness and lightweight, what will permit easier installation and maintenance. With airborne antennas on large jumbo jets, installation requirements are not as limited compared to very small aircraft and helicopters, because even small jets have more space on fuselage for antenna installations. Small jets and especially helicopters require low profile and lightweight equipment.

The antenna requirements are the same in jumbo intercontinental aircraft, although more stringent conditions are required to satisfy ICAO standards. However, the low air drag influence is one of the most important requirements for aircraft antennas. Therefore, a phased array is considered to be the best candidate for aircraft and helicopters because of its very low profile, convenient mechanical strength and easy installation.

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