Advanced Media Networks

High Accuracy Antenna System

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Overview

Antenna systems designed to steer to, align, acquire and/or dynamically track geostationary or asynchronous satellites are typically high cost, purpose built systems with long lead times for delivery and installation. Existing systems designed to transmit and receive at higher data rates (20-90Mbps) in the Ku-band typically use a 3.7 meter or larger antenna system. C-band systems are even larger. Lower look angles require even much larger dishes. High accuracy, fixed site steerable antenna systems can cost upwards of $100,000 depending on size and complexity. Engineering and installation costs combined with advanced RF and ground station electronics equipment, monitoring and control systems can quickly escalate costs to millions of dollars. Highly trained installation crews consume weeks or months of time to install, setup, test and turnover operation of these systems to satellite service companies. Transportable and truck mounted Satellite News Gathering (SNG) antenna systems designed to transmit digital video or data can cost from $200,000 at the low end to over $750,000 at the high end. These systems use reflectors ranging in size from 1.4 meters to 3.7 meters and above. Additional video and audio equipment and video/audio encoding gear can add an additional $300,000 to $1,000,000 to the overall system cost.

Figure 1 - Typical Earth Station Configurations

Most of the commercial grade steerable or tracking antenna systems for commercial C or Ku band satellite transmission and reception integrate complex gearing systems or motors and/or heavy duty motors with specialized hardware controllers to align and steer antennas to the correct location. They typically have only two degrees of freedom (azimuth and elevation) with linear polarization usually achieved by manual or motor controlled movement of the feed horn assembly. Less expensive antennas, in the $600 to $3,000 range use manual mechanical adjustments and low cost back frames and tend to require highly trained personnel to adjust and align. They can be difficult to optimize and reliably maintain performance characteristics particularly for higher data rate applications in transmit mode. Improper installation and normal wear and tear can result in geometric distortion and resulting poor performance.

Design Objectives

Based on the preceding observations, **A**dvanced **M**edia **N**etworks' decided to produce a unique antenna system based on the following design objectives:

1. Make an affordable and transportable nomadic antenna system that can be shipped anywhere in the world,

2. Develop automation software for antenna alignment and optimization so that a lightly trained person could use the system.

3. Optimize the system to provide very high data rate transmission and reception with low-cost, off-the-shelf, type-approved reflectors of modest size.

4. Design and engineer the antenna system to provide precision reflector support to prevent geometric distortion of the antenna reflector and feed horn assembly

5. Use a precision motorized control system to acquire, optimize and maintain beam accuracy with true bore sight alignment and precise polarization to ensure extremely high performance within all regulatory rules required for co-satellite and co-channel interference.

6. Keep the signal optimization so precise that high data rate transmission and reception requirements can be maintained at all times and under adverse conditions, such as rain or terrain obstacles.

7. Design and engineer the controller head assembly using a modular approach to provide extensibility to any reflector and feed horn assembly or to any other type of communications system (e.g., free space laser or terrestrial wireless) that requires fast, easy-to-use, high accuracy automatic alignment.

8. Design and engineer an integral amplifier mounting system that was as close as possible to the feed horn to minimize signal loss in the waveguide assembly.

9. Design and engineer an all-digital software-driven auto-alignment system integrated into the antenna system in a way that any satellite contained in a software database can be automatically located, acquire signal, lock on and optimize signals within ten minutes.

10. Provide remote control and monitoring of all antenna functions via in-band or out-of-band connections

11. Provide system extensibility for easy product refinements and enhancements, such as lighter weight materials, different reflector and feedhorn assemblies and smaller sizes.

Design Characteristics

Below is a simplified diagram of the basic design concept for the antenna system and components. Reflector shapes and sizes, feedhorns and amplifiers can be easily adapted to the basic system.

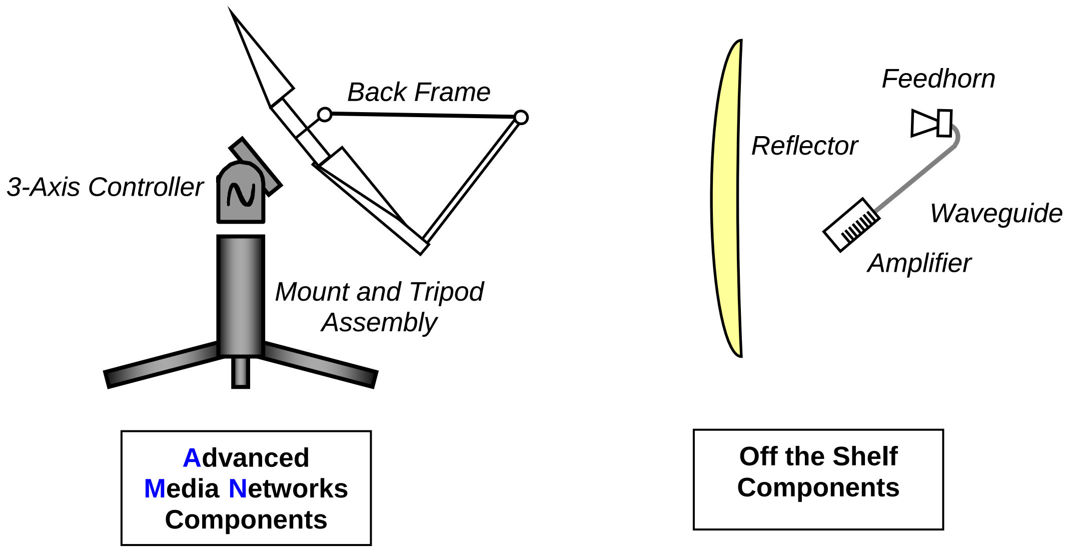

Figure 2 - Simplified Diagram of Antenna System

Design Features – Electromechanical and RF

The **A**dvanced **M**edia **N**etworks' antenna system uses a modular approach that separates the motorized multi-axis controller and pointing system from the base assembly and the reflector/feed horn assembly as shown in ***Figure 2***. This modular approach allows for highly precise alignment in the antenna system without redesigning the entire mounting, pointing, and alignment systems. The weight-bearing components of the antenna system cantilever from the steering head using weight-bearing gas springs designed to offset the weight of the reflector, amplifier and feed horn assembly. Gas springs lower motor torque and allow for a compact head with high load bearing capacity. Zero backlash gearing ensures stepper motor accuracy of .01 degrees. These design features allow the basic design to be adapted to other communications system, such as free-space laser or terrestrial microwave to the controller assembly.

The back frame can be customized to any antenna/reflector system for other communications system and deliver very high precision while maintaining better mechanical and structural stability. If a reflector and feedhorn system has sufficient structural integrity, it can also be directly mounted to the controller assembly.

Use of the gas spring/cantilever approach also allows simple upgrades to support higher weights and larger reflector assemblies using the same basic design.

The integral back frame with supporting struts and cradles for the satellite power amplifier provides a simple and mechanically sound system for providing excellent RF performance at a moderate price. Integrating the waveguide and amplifiers into the dish assembly provide even better performance and faster setup times at remote nomadic locations.

Advanced **M**edia **N**etworks has developed cradle designs that can handle amplifiers up to 450 watts.

Major Design Features – Automation Control and Tracking Software

The antenna system was designed to allow simple, browser based local or remote monitor and control of the entire motion controller and the RF transmission/reception chain. This document only describes monitor and control functionality for the multi-axis controller assembly. Additional software to remotely control video-conferencing equipment, initiate high-speed file transfers, and set ancillary equipment such as satellite gateways is also available. Hardware communications to the controller assembly is accomplished via direct RS-485 connection to the controller assembly. Hardware controlled in the head assembly includes a motor controller, two digital compasses (a GPS compass and a magnetic flux gate compass), a GPS receiver for latitude, longitude and absolute time information and an inclinometer. A single Intel-based computer running under Linux OS with a web server performs all hardware control and all software calculations necessary to acquire, lock on and optimize to a given satellite from the database of satellites in the server using a simple browser-based GUI.

User interaction is very simple and straightforward using a Java applet running in a browser. The pointing acquisition and optimization is initiated by having the user select a given satellite and press the Automate icon on the browser. Using **A**dvanced **M**edia **N**etworks' proprietary hardware and software solutions, the dish then points the antenna to the correct position, acquires the signal and optimizes signal strength. On the nomadic version of the antenna system, the equipment is bundled as part of a hardened portable rack assembly with a cable harness running directly to the controller assembly.

The antenna automation subsystem consists of four software components and six hardware devices. The software consists of a primary Linux server that communicates with the dish client and all of the hardware, a secondary Linux server that performs all computations required to determine the position of a satellite, a Java applet that provides the user interface in a browser and a database of satellite orbital parameters and beacon frequencies. The hardware includes a motor controller that moves the dish, a compass (magnetic and or GPS) that determines the heading of the dish, a GPS receiver that provides latitude, longitude and time information, an inclinometer that measures dish elevation, a beacon receiver that reads the signal strength of a satellite beacon and an analog to digital converter that reads signals at a faster rate.

The user connects to the primary dish server through a Java applet running in a browser. The pointing process initiates when the user selects a satellite and presses the “Automate” button. The primary dish server first determines if the dish is in a calibrated state, i.e., if the earth position and dish position information is current. If not, calibration begins by leveling the elevation and polarity axes of the dish. The inclinometer sends current elevation and polarity data via RS-485 to the pointing software. The software queries the GPS receiver to determine the current latitude, longitude and time. If equipped with a GPS compass, the current azimuth is also determined from GPS data. Otherwise, azimuth is read from the magnetic compass. The declination from true north is computed using the standard Department of Defense World Magnetic Model algorithm. Next, the overall tilt of the dish is determined to create a set of synthetic axes that allow accurate pointing when the dish is not level. An alternate method of manual leveling is also available for the user via software. This completes the initial dish calibration.

The antenna look angle is then calculated using an implementation of the NORAD SGP4/SDP4 orbital prediction model. The dish is moved to the calculated position and the beacon receiver is queried to determine if the dish is locked on the satellite’s beacon. If lock is not achieved, a coarse azimuth search is performed. If the satellite is not located during this search, a spiral search pattern is then initiated. Should this fail, an error message is sent to the client and automation is terminated and the user can try again and be prompted to check for physical obstacles in the path.

Once the dish is locked on the satellite, a fine position determination procedure is begun. This procedure essentially centers the dish on the satellite beacon by finding the horizontal and vertical edges of the signal and positioning the dish at the “center of the box”. At this point tracking is begun. At intervals of approximately .10 (one-tenth) second, the satellite’s position is re-calculated and if it has changed by a user configurable amount (usually .01 to .1 degree) the dish is moved to the new position. Tracking continues indefinitely until the user aborts the procedure.

Remote control of the pointing assembly is possible using in-band or out-of-band connections to each of the installed units in any global location. Each remote installation only requires a Linux server with **A**dvanced **M**edia **N**etworks’ proprietary software and hardware and a reliable network connection.

Applications

- Our unique design allows low-cost, steerable fixed site antennas for rooftop or ground deployment with remote monitor and control from any location. This means that a central NOC or distributed worldwide monitor and control centers can easily monitor and change satellites or "shop transponders" for event-driven venues, and digital cinema applications.

- "Instant" NOCs can be quickly installed at multiple sites at much lower costs than traditional installations. To complement the antenna systems, **A**dvanced **M**edia **N**etworks also offers a transportable self-contained outdoor mini-NOC that contains all necessary transmission equipment for a dual-threaded, redundant transmission system with full battery backup and automatic cutover systems in the event of equipment failure. A system can be up and running on one day. Applications include digital-video transmissions from 8 to 90 Mbps SCPC or MCPC, full duplex, moderate to high-speed IP connections or multicast applications.

Future Applications

- Systems that can accurately track inclined orbit, asynchronous or elliptical orbit satellites. Many satellites that still have useful life are in an inclined orbit with a predictable periodicity. **A**dvanced **M**edia **N**etworks' has tested its antenna system on some of these satellites with favorable results.

- Multiple sizes, lighter weight systems and higher efficiency reflector designs can be developed at low engineering costs, since the design approach is modular.

Technical Specifications

1. Antenna System Performance – Electrical and RF *

*Based on **A**dvanced **M**edia **N**etworks' proprietary back frame and motion-controlled alignment system and proprietary pointing software. (Prodelin Series 1251 Reflector)

2 Port Receive/Transmit Combiner	Ku-Band	C-Band
Antenna Size - Diameter	2.4 meter (96 inches)	2.4 meter (96 inches)
Frequency Bands Receive Transmit	10.7 - 12.75 Ghz 12.75 - 14.80 Ghz	3.625 – 4.2 Ghz 5.850-6.425 Ghz
Midband Gain, Linear Polarization Receive Transmit	 47.6 dBi 49.2 dBi	 38.0 dBi 42.0 dBi
Measured data throughput from 2.4 meter to 2.4 meter antenna at: Eb/No of 7.5 dB and FEC of .875 257 watts output power, clear sky, 36 MHz transponder geostationary satellite (PAS-9 and G10R) Transmit Receive	 60 Mbps 60 Mbps	 ------ ------
Receive Noise temp 10° elevation	52°K	43°K
Receive Noise temp 20° elevation	39°K	33°K
Receive Noise temp 30° elevation	37°K	36°K
Receive Noise temp 30° elevation	37°K	36°K
Antenna G/T at 15° elevation	27.7 db/K	------
Antenna G/T at 35° elevation	28.0 db/K	------
Antenna G/T at 45° elevation	28.1 db/K	------
Sidelobe Envelope, Co-Pol (dBi)		
$100\lambda / D\ \theta \leq 20°$	29-25 Log θ dBi	29-25 Log θ dBi
$20° < \theta \leq 26.3°$	- 3.5 dBi	- 3.5 dBi
$26.3 < \theta \leq 48°$	32-25 log θ dBi	32-25 log θ dBi
$\theta > 48°$	-10 dBi (averaged)	-10 dBi (averaged)
VSWR	1.3:1 Maximum	1.3:1 Maximum
Feed Interference Receive Transmit	 CPR 229F CPR 137 or Type N	 WR 75 WR 75 or Direct Radio Mounting

2. Antenna System Performance - Mechanical

*Based on **A**dvanced **M**edia **N**etworks' proprietary back frame and motion-controlled alignment system and proprietary pointing software. (Prodelin Series 1251 Reflector)

Reflector Material	**Glass Fiber Reinforced Polyester SMC**
Antenna Optics	Prime Focus, Offset Feed
Elevation Adjustment Range	0° - 90° from Horizontal Plane
Azimuth Adjustment Range	360 ° Continuous
Boresight Axis Range**	360 ° Continuous
Tracking Range of Motion Control System for Elevation	0° - 90° Continuous)
Slew Rate of Motion Control	2.5 °/sec (optional higher slew rates)
Satellite Acquisition Time	2 minutes
Assembly and Setup Time	Typically under one hour
Shipping Weight	745 lbs. (338 kg)

** The Advanced Media networks Antenna System moves the entire reflector on the bore sight axis

3. Antenna System Performance - Environmental

*Based on **A**dvanced **M**edia **N**etworks' proprietary back frame and motion-controlled alignment system and proprietary pointing software. (Prodelin Series 1251 Reflector)

Operating Temperature	**- 40° to 125° F**
Wind Loading	50 mph (80 km/h) operational 125 mph (201 km/h) survivable
Rain	½" inches (12mm) per hour
Solar Radiation	360 BTU/hr/ft^2
Relative Humidity	100 %
Shock and Vibration	As encountered by commercial Air, Rail and Truck Shipment
Atmospheric Conditions	Salt, Pollutants and Contaminants as encountered in Coastal and Industrial Areas

4. Type Approvals – for current system

Based on the off-the-shelf reflector and feed assembly from Prodelin, the antenna system is certified for operation with the following satellites:

INTELSAT IA041A00

EUTELSAT EA-V029/32

HISPASAT HIS-ET-96221-10005-PRO

CHINASAT 99033

ANATEL 118298-ZZZ995

APT USA002

SINOSAT 99029

PT SATEUT, ASIASAT, ETSI, and Russian Ministry of Communications

System in Use

The following photographs show the assembled system and all of its major components. This version is designed primarily for use as part of Advanced Media Networks's *ShowRunner Services* that has been positioned to service the motion picture and television production industry worldwide. It has been used in service on several recent film productions, including such major productions as Harry Potter and Blackhawk Down. The nomadic system has been used in Europe, North America and will soon be used in Australia.

Assembled System

Rugged Field Electronics

3-axis Control Head

Collapsible Tripod

Advanced Media Networks' has patented the entire auto alig[illegible] antenna design under the following patents:

Patent Summary

Patent Name	Patent Number	Issue Date
STEERABLE ANTENNA ASSEMBLY	6,462,718	October 8, 2002
QUICK DISCONNECT ASSEMBLY	6,462,715	October 8, 2002
FEED LEG ASSEMBLY	6,441,798	August 27, 2002
ALIGNMENT JIG ASSEMBLY	6,466,179	October 15, 2002
ADJUSTABLE HORN MOUNT ASSEMBLY	6,466,175	October 15, 2002
BACK FRAME ASSEMBLY	6,531,992	March 11, 2003
MOUNT AND CONTROLLER ASSEMBLY	6,630,912	October 7,2003