K- and K_a-band Mobile-Vehicular Satellite-1'racking Reflector Antenna System for the NASA ACTS Mobile Terminal

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ABSTRACT

This **paper** describes the development of the K- and K_a-band mobile-vehicular satellite-tracking reflector antenna system for NASA's ACTS Mobile Terminal (AMT) project, ACTS is NASA's Advanced Communications Technology Satellite, The AMT project will make the first experimental use of ACTS soon after the satellite is operational, to demonstrate mobile communications via the satellite from a van on the road, The AMT antenna system consists of a mechanically steered small reflector antenna, using a shared aperture for both frequency bands and fitting under a radorne of 23 cm diameter and 10 cm height, and a microprocessor-controlled antenna controller that tracks the satellite as the vehicle moves about, The RF and mechanical characteristics of the antenna and the antenna tracking control system are discussed, Measurements of the antenna performance are presented,

INTRODUCTION

The Jet Propulsion Laboratory (JPL) has developed several mobile vehicular antenna systems for satellite applications [1- 10]. JPL has installed these antenna systems in vehicles equipped as mobile communications laboratories [11 - 12] and field-tested the equipment. The results of the field trials have been documented in the literature [1 3-18].

Recently a new K- and K_a-band mobile vehicle antenna system has been developed by JPL for use with NASA's Advanced Communications Technology Satellite (ACTS). The Space Shuttle will launch ACTS into its geostationary orbit in 1993 at 100 deg West longitude, above the mid-Western US, The" new mobile vehicle antenna development is the AMT reflector antenna system, which will be used to demonstrate direct-dial voice, video and data communications via ACTS from a mobile vehicle while traveling in the Southern California area [19]. The reflector antenna system installs on the roof of the AMT vehicle.

ANTENNA ASSEMBLY

Figure 1 is a picture of the AMT reflector antenna shown with a transparent rnoek radome; the actual radome has the same hemi-ellipsoidal shape but is opaque. The external dimensions of the radome are 23 cm diameter and 10 cm peak height, The radome is a 4 mm thick "A-sandwich" and imposes insertion losses of 0,2. dB at 20 GHz (K band) and 0.4 dB at 30 GHz (Ka band). A Vellox hydrophobic coating that is nearly electromagnetically transparent keeps water from wetting the radome surface and allows the AMI' to maintain communications in light rain. Figure 2 is an exploded view of the antenna assembly. All of the antenna components mount directly to the motor, which makes the assembly simple, compact and rugged. The motor is a 1.3 cm tall direct-drive two-phase stepper motor. The reflector and feed horn mount on a disk that attaches directly to the motor (direct-drive) to accomplish azimuthal steering. Below the disk an optical encoder verifies that the motor steers the antenna to the proper angle. Figure 3 is an RF block diagram of the antenna.

The antenna incorporates an offset reflector configuration to avoid feed horn blockage. The reflector is constrained to fit with the feed horn under the radome and is relatively small, only about four by ten wavelengths at the 20 GHz band. The basically elliptical reflector shape maximizes gain while providing a relatively wide elevation beamwidth to relax the need for satellite elevation tracking. The shape of the reflector is the intersection of a paraboloid and an elliptical cylinder, with the cylinder oriented so the projection of the reflector surface is nearly a simple ellipse as viewed from both the feed horn and the satellite directions; this orientation is important to ensure good illumination of the reflector by the feed horn and a reasonably symmetrical antenna elevation pattern -- it also contours the shape of the reflector to fit well under the radome. The reflector mounts to a manually adjustable fixture that sets the nominal elevation angle of the antenna beam to potentially allow operation with ACTS in any region of the Continental United States (30-60 deg elevation).

All of the antenna RF components except the reflector and rotary joint are integrated into a single, rigid, electroformed assembly to reduce RF losses and increase mechanical integrity. Figure 4 shows the feed horn assembly, consisting of the feed horn, orthomode transducer and upper diplexer (the components above the rotary joint in figure 3). The feed horn assembly is a waveguide system that distributes both the 20 and 30 GHz signals from the rotary joint to the feed horn. The one feed horn is used for both frequency bands, with vertical polarization for the 20 GHz downlink and horizontal polarization for the 30 GHz uplink -- ACTS requires these polarizations. Immediately behind the feed horn is the orthomode transducer. The orthomode transducer combines the two frequency bands from two different ports and channels them to the feed horn after orienting them with the proper polarizations. The upper diplexer spatially separates the two frequency bands and distributes them to the respective ports of the orthomode transducer, The diplexer makes up most of the lower portion of the assembly. The RF losses through the feed horn assembly are about 0.3 dB at 20 GHz and 0.5 dB at 30 GHz.

The rotary joint distributes the RF signals to the antenna components turned by the motor and provides the sole RF connection on the underside of the antenna. It is a single-channel coaxial unit, and as such is a relatively small unit that imposes a minimum of frictional torque. The rotary joint is only 1.3 cm in diameter and installs in the very center of the motor assembly. The choice of such a small rotary joint is a major factor in achieving the overall reduction in size of the antenna. The RF loss through the rotary joint is about OS dB at both frequency bands.

SATELLITE TRACKING

Tracking the satellite requires only azimuthal steering (one-dimensional) since the antenna elevation beamwidth is wide enough to accommodate typical vehicle pitch and roll variations within any single region of operation. The satellite tracking system is a Motorola 68030 microprocessor-based hybrid feedback/feed-forward system; it steers the antenna in azimuth angle by controlling the motor in response to pointing information obtained from an inertial vehicle yaw rate sensor (feed-forward) and a mechanical dithering pointing error signal (feedback) simultaneously. The rms tracking error is only a small fraction of a degree, It is able to complete a full azimuth scan and acquire the signal in about 7 sec.

The technique used to measure antenna azimuth pointing error for tracking feedback is mechanical dithering. Mechanical dithering involves rocking the antenna left and right sinusoidally (in azimuth angle) 1 deg in each direction at a 2 Hz rate to determine if the antenna is pointed in the direction of strongest signal. The satellite sends a special beacon for this purpose; the AMT system RF transceiver detects the beacon through the antenna and provides the detected signal to the antenna control ler computer. By correlating the received signal level reported by the transceiver with the commanded dithering of the antenna angle, the antenna controller computer determines the sign and magnitude of any pointing error. Figure 5 shows the measured mechanical dithering pointing error detection function,

ANTENNA RF PERFORMANCE

Figures 6-9 present the elevation and azimuth co- and x-pol 20 and 30 GHz far-field patterns of the antenna, The patterns show the elevation coverage centered at 46 deg for operation through ACTS in southern California. Requirements for the antenna performance are made over a 12 deg range of elevation angle, centered at 46 deg -- this range accommodates +/- 6 deg typical vehicle pitch and roll variations while travelling paved roads.

Over the required elevation angle range the minimum gain at 20 GHz is 19 dBi with a maximum of 22.5 dBi, and at 30 GHz the minimum gain is 19 dBi with a maximum of 23.5 dBi. The elevation backlobes and azimuth sidelobes are more than 20 dB down from the main lobe, Peak x-pol is no greater than -15 dB. These measurements are referred to the TWTA and LNA ports of the lower diplexer, diagrammed in figure 3.

Over the required elevation angle range the receive sensitivity ratio (antenna gain over system noise temperature, or G/T) is a minimum of -6 dB/K, with a peak of -2.5 dB/K. The system noise temperature is 320 K, of which 260 K is due to the LNA and all other receiver components below it (not shown in figure 3). The remaining 60 K is due to the antenna (everything above the LNA in figure 3), including cosmic and sky noise as well as thermal noise introduced by the dissipative losses of the antenna components (about 1 dB in all). When the antenna is pointed directly at the sun, the receive system noise temperature increases by only 0.1 dB (5 K).

The antenna handles up to 10 W transmit power applied at the lower diplexer by the TWTA. With the maximum of 10 W transmit power the maximum EIRP ranges from 30-33.5 dBW, depending on elevation angle.

Transmit-induced receiver noise (receiver desensitization) is not a problem with this antenna, There is no measurable degradation of receive sensitivity (+/- 0.05 dB) resulting from simultaneous transmission up to the maximum power level, 10 W.

CONCLUSION

JPL has successfully developed a mobile vehicle antenna system for NASA's K/K_a-band ACTS Mobile Terminal program, and initial tests show that the antenna and its satellite tracking system perform very well. It is small in size and rugged for operation in the mobile environment. It will be used for the first experimental use of the ACTS satellite soon after the satellite's launch. The AMT will demonstrate voice, video and data communication through the ACTS satellite from a mobile vehicle traveling roads in the southern California area,

ACKNOWLEDGMENT

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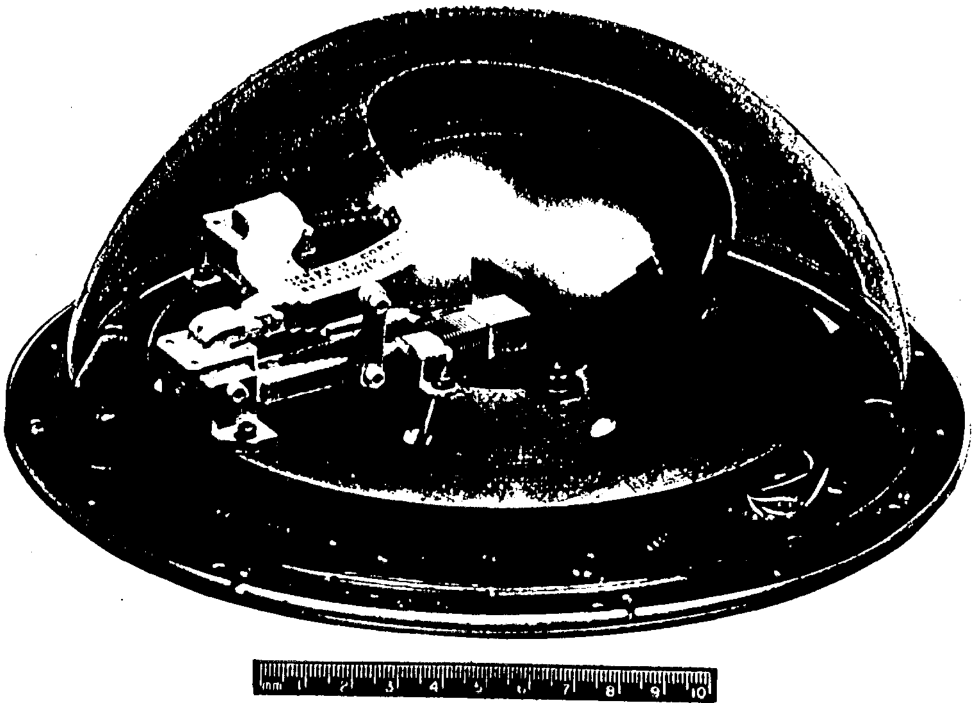

Fig. 1 AMT Reflector Antenna

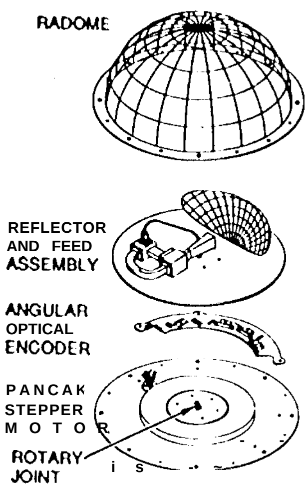

Fig. 2 Reflector Antenna Exploded View

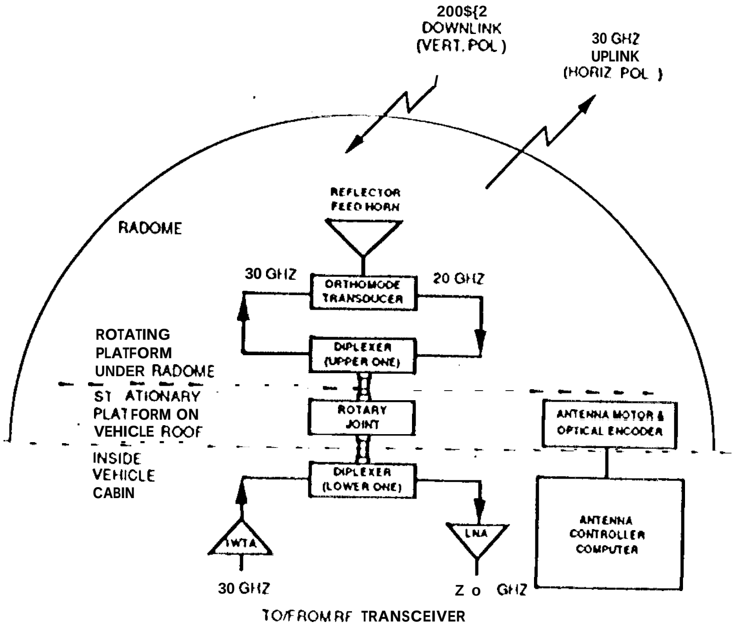

Fig. 3 Reflector Antenna Block Diagram

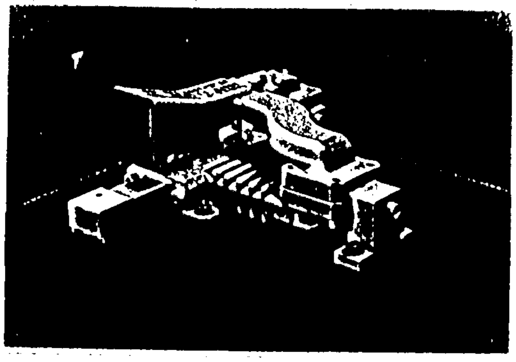

Fig. 4 Feed Horn Assembly

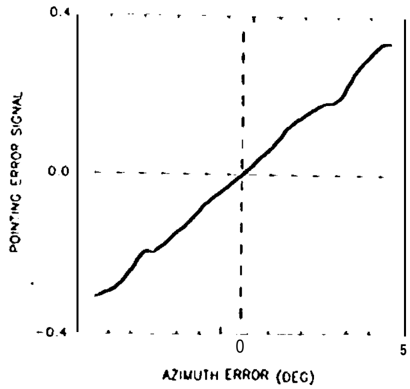

Fig. 5 Mechanical Dithering Pointing Error Detection

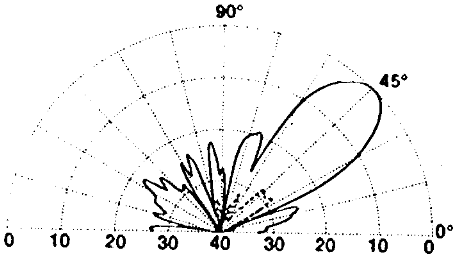

Fig. 6 Elevation Pattern, 20 GHz, Co- and X-pol

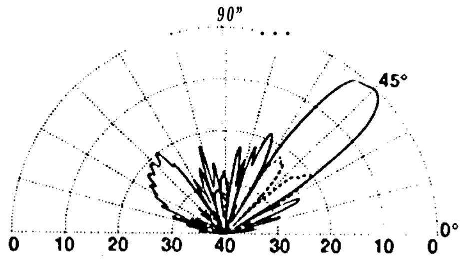

Fig. 7 Elevation Pattern, 30 GHz, Co- and X-pol

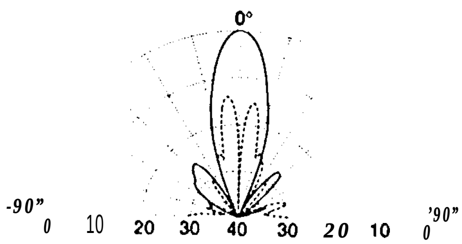

Fig 8 Azimuth Pattern, 20 GHz, Co- and X-pol

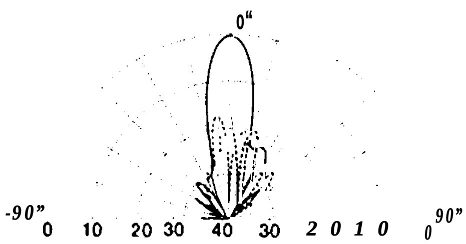

Fig 9 Azimuth Pattern, 30 GHz, Co- and X-pol