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COMMERCIAL APPLICATIONS OF THE ACTS
MOBILE TERMINAL MILLIMETER-WAVE ANTENNAS

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ABSTRACT

NASA's Jet Propulsion Laboratory is currently developing the Advanced Communications Technology Satellite (ACTS) Mobile Terminal (AMT), which will provide voice, data and video communications to and from a vehicle (van, truck, or car) via NASA's geo-stationary ACTS satellite using the K- and K_a-band frequency bands. The AMT is already planned to demonstrate a variety of communications from within the mobile vehicular environment, and within this paper a summary of foreseen commercial application opportunities is given. A critical component of the AMT is its antenna system, which must establish and maintain the basic RF link with the satellite. Two versions of the antenna are under development, each incorporating different technologies and offering different commercial applications.

INTRODUCTION

The ACTS satellite is scheduled for launch in 1993, and the first demonstrated use of the satellite will be made by the AMT [1]. From a van and a car that will travel along roads and highways a demonstration of voice, fax, and compressed video communication will be made. The communication is two-way, between the vehicle in Los Angeles, California and a base station in Cleveland, Ohio via the ACTS satellite as shown in Figure 1. The AMT antenna which mounts to the vehicle roof with a diameter of 8 inches and height 3 inches must track the direction to the satellite as the vehicle moves about. The antenna is designed with a wide enough elevation coverage so that only azimuthal tracking is required, and a thin microprocessor-controlled, pancake-shaped motor drives the antenna azimuth angle. Two versions of the antenna are being developed and both will be the same size and use the same motor for tracking.

The requirements to which the antennas are being designed ensure that the overall AMT will provide a high performance measure. In addition to simply operating in a mobile environment for which shock and vibration are characteristic, the antenna must adhere to both RF and tracking requirements.

For the uplink transmit link from the mobile vehicle, the AMT must generate 22 dBW EIRP minimum power. The transmit power density must be large enough to accommodate the required communications rates but low enough that the transmit beam is not a hazard for people standing near the vehicle. For the downlink receive link to the vehicle the AMT must provide sufficient receive sensitivity to accommodate the downlink communications rates. The minimum requirement is -8 dB/K, and typically losses within the antenna must be minimize to make the sensitivity this high. The tracking requirements are that the AMT compensate for a maximum vehicle yaw (turn) rate of 45 deg per sec. When the communications link has not yet been established, and the AMT must acquire the satellite, the requirement is that acquisition be complete and the link established within 10 sec. While the vehicle is traveling and the antenna tracking the satellite, the required tracking accuracy is 0.8 deg rms. Since the ACTS satellite will be in geostationary orbit, the AMT tracking system must achieve essentially an inertially-stabilized antenna pointing system. As the host vehicle turns, the position of the antenna is adjusted to insure that the antenna continuously points towards the satellite. An embedded microprocessor controls the antenna's movements.

REFLECTOR ANTENNA

The reflector antenna is the first version of the AMT antenna to be developed. It represents a relatively low risk development for the short available schedule. The reflector requires that the AMT incorporate TWT (tube) technology, in order to meet the uplink transmit EIRP requirement. A single TWT is employed to generate the 1-3

watts required to maintain the mobile satellite uplink. Although not normally required, the reflector antenna is capable of handling the full 15 watts that the TWT can generate at 30 GHz. A single low noise amplifier (LNA) unit with 2.5 dBNF ensures a sufficient receive system sensitivity at 20 GHz. Waveguide plumbing connects the reflector antenna to the TWT and LNA with minimum loss, so that the overall RF performance is not significantly degraded.

The reflector shown in Figure 2 consists of a waveguide feed horn assembly and a reflecting surface. The feed assembly consists of a diplexer, orthomode transducer (OMT), and a feed horn, which faces the reflecting surface. The diplexer has a coaxial port which connects to the RF transceiver of the AMT through a rotary joint, and two waveguide ports (REV & XMT) which connect to the OMT. The OMT combines the signals from the two diplexer ports into a single waveguide port with the proper waveguide modes at the two ACTS frequencies so that a single feed horn may be used to properly illuminate the reflector surface. The reflector surface is a section of a parabolic surface of revolution, with its boundary defined by the intersection with a cylindrical ellipsoid. The projected view of the reflecting surface appears nearly elliptical both from the view of the feed horn and the direction of propagation. The reflector is only a few wavelengths across both its dimensions, and so is electrically much smaller than the simple reflector antenna application, and its beam less collimated in the same regard.

COMMERCIAL APPLICATIONS OF THE REFLECTOR ANTENNA

Commercial applications which would make use of the reflector antenna are those which need to rely on technology which has already been extensively tested and proven. The reflector with its TWT & LNA represent a classical system which has for decades been used and proven in radar applications, although the AMT does not utilize these technologies in the same (radar) manner.

One such application would be remote news gathering vehicles which now depend on cellular systems for communication in urban centers; those systems do not operate in rural areas and could be supplemented by use the AMT system. This application would support video and audio from the most remote rural sites, world-wide. This service would not complete with existing cellular telephone systems, but supplement them instead. Within metropolitan areas more use would be made of the cellular system, while the direct satellite link could be exploited in rural areas.

Another such application might be emergency communication vehicles, which could respond immediately to disaster sites and provide needed communication via satellites independent of local power outages.

PLANAR ARRAY ANTENNA WITH MMICs

The planar array antenna will be developed after the reflector antenna, although its design has already begun. This antenna offers MMIC technology which is more advanced, yet less proven, than that of the reflector antenna.

The planar array antenna shown in Figure 3 utilizes solid state MMIC transmit (power) and receive (low-noise) amplifier circuits. These MMICs are integrated into the antenna on the array itself so that minimal transmission line length exists between the MMIC LNAs and the array antenna elements. The short lengths of transmission line keep the losses very low and the antenna efficiency and sensitivity high. The array is organized into 12 columns (groups) of antenna elements, and each column is directly connected to a receive or transmit amplifier. This arrangement provides for a direct spacial combination of the receive signal or transmit power. In this manner the transmit power amplifier in each column must only provide a fraction of the power that is radiated by the entire array, and this power level (≈ 0.1 watt) can be supplied by MMIC circuits. Since the MMICs are integrated very near the antenna elements, the short interconnecting transmission lines present a smaller amount of loss, and the antenna as a whole is more power efficient than an antenna system which must distribute all transmit power from a single high-power source through longer transmission lines to each of the antenna elements.

COMMERCIAL APPLICATIONS OF THE PLANAR ARRAY WITH MMICs

Commercial applications of the planar MMIC antenna require a more costly initial investment that the reflector because of the need to achieve mass production of a presently more expensive technology. Once mass production is

established and a market is available, it is expected that the commercial markets will eventually allow the overall costs to reduce even below that of the reflector antenna.

One exciting commercial application is in the new and growing field of personal communications. Today a wrist watch can be purchased that contains a beeper to notify the user of calls. The planar MMIC array is a first step toward the development of a miniaturized personal satellite communication handset. Such a handset would allow communication anywhere in the world.

Because of the modular design of the planar MMIC array antenna, its MMIC circuits may be readily enhanced to include electronic phase control, allowing phase-array electronic azimuthal steering, without having to modify the basic antenna design concept. Such a commercial application would be capable of tracking a high-speed vehicle such as a plane flying across the field of view at a relatively constant elevation angle.

CONCLUSION

The launch of the ACTS satellite will bring about new commercial opportunities, which the AMT antennas will begin to demonstrate, the AMT reflector antenna provides a system based on proven technologies, and the AMT planar MMIC array provides a "state-of-the-art" antenna system which points the direction to the future of personal, hand-held satellite communication systems.

ACKNOWLEDGEMENT

REFERENCES

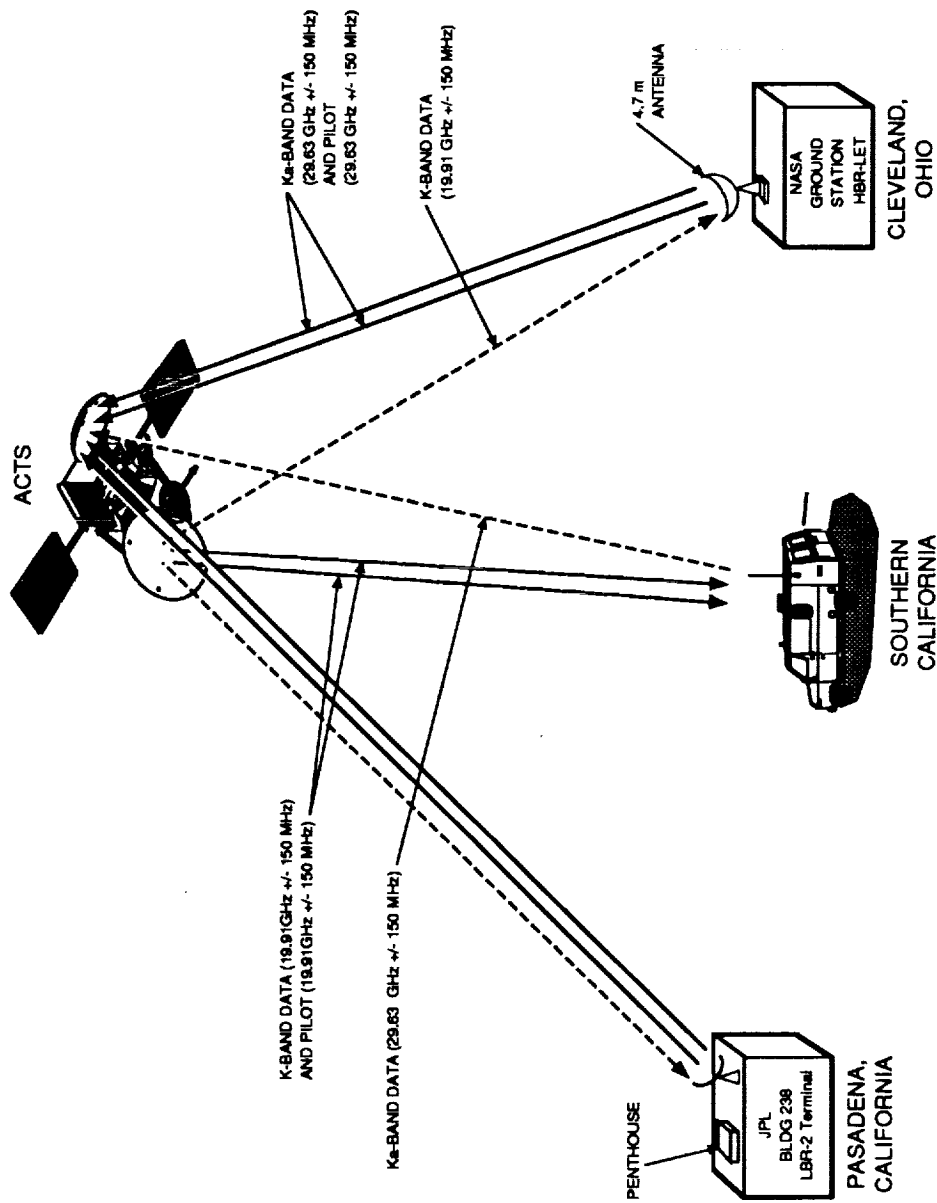[1] K. Dessouky, et al., "The ACTS Mobile Terminal," JPL SATCOM Quarterly, No. 2, July 1991.

Figure 1. AMT experimental setup with millimeter-wave antennas mounted on top of mobile vehicle.
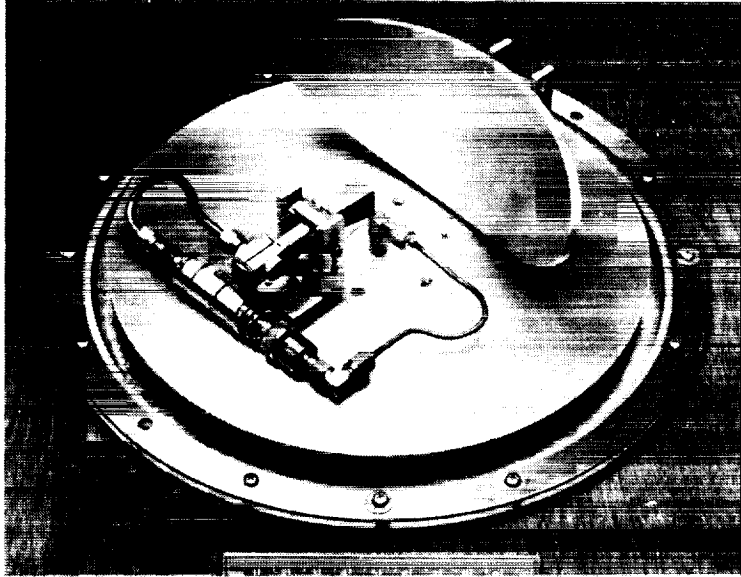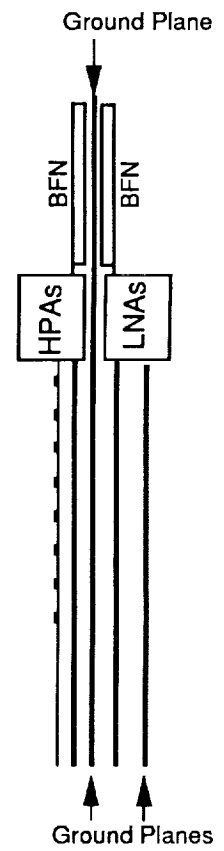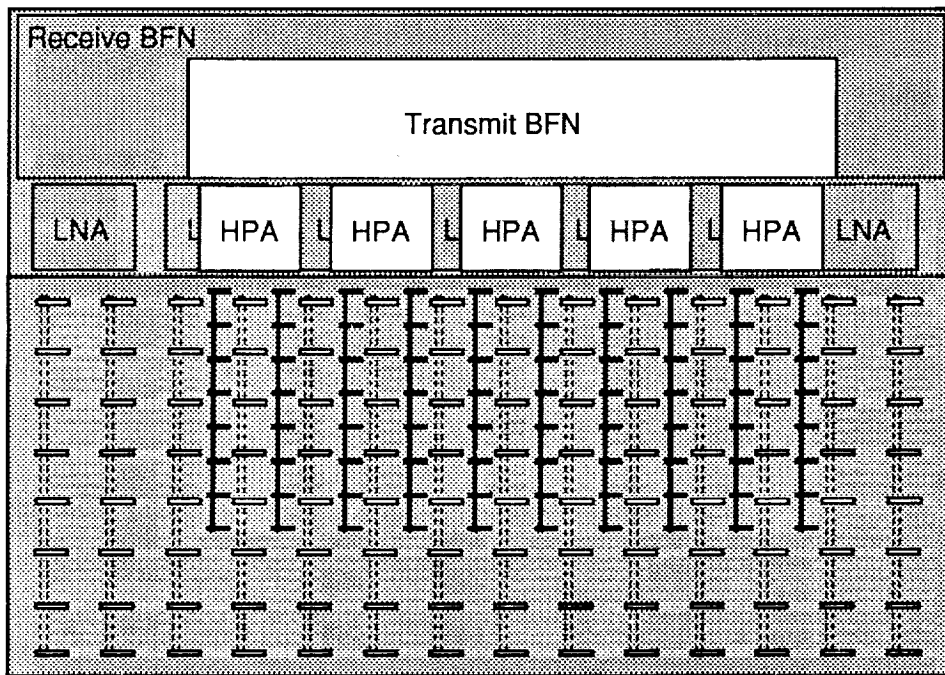
Figure 2. AMT Reflector Antenna and Test Platform

Figure 3. Concept drawing of the AMT Planar Active Array