A NEW HIGH EFFICIENCY, AGILE BEAM SCANNING, BROADBAND TRACKING ANTENNA FEED

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ABSTRACT

Two different types of tracking feeds are currently used in the majority of telemetry tracking antenna systems when autotrack operation is required. They are of the conical scanner or of the single channel monopulse family and they employ well known technologies.

In broadband applications, these feeds all suffer from the same inherent degradation in efficiency caused by their inability to maintain a constant crossover loss value and by their failure to properly illuminate the reflector.

In high dynamics situations they can also generate unwanted and sometimes detrimental modulation whenever on-axis tracking is not maintained.

In addition, currently available versions of the conical scanner are not capable of high scan rates or of scan rate agility and they are ill-suited for use in tracking systems based on non-orthogonal axes positioners.

This paper describes a new high efficiency tracking feed system based on proven conical scanner technology. Its design incorporates features such as variable crossover, steerable beam, high scan rates, scan rate agility as well as stable reference coordinate system. In addition to these features, this new feed is also capable of delivering, in all but one operational category, levels of performance superior to that achievable to date by any other implementation of the conical scanner or of the single channel monopulse technology.

KEY WORDS: Broadband Tracking Antenna Feed, Efficiency, Beam Steering, Scan Rate, Overhead Pass, Non Orthogonal Axes Positioners
INTRODUCTION

Two different types of tracking feeds are currently used in the majority of telemetry tracking antenna systems when autotrack operation is required. They are of the conical scanner or of the single channel monopulse family. They both employ techniques well described in the literature and a number of papers (1), (2) and (3) have been written detailing the relative advantages of each of these technologies. Various implementations of these concepts are currently available featuring varying levels of performance.

In broadband applications, these feeds are incapable of maintaining a constant crossover loss value and cannot provide optimum illumination of the reflector over a wide frequency band. In the 1435 to 2400 MHz frequency band, typical handling of the crossover level problem results in a feed design yielding crossover loss values varying from the needed minimum .25 dB at low frequencies up to .80 dB at high frequencies. This approach results in an actual gain reduction of .55 dB at 2400 MHz and necessitates adjustment of the servo loop gain in accordance with the frequency used for tracking. Similarly, typical handling of the under/over illumination problem results in a feed design yielding less than optimum efficiency at a number of frequencies in the operating band. This causes as much as a 0.6 dB reduction in the actual gain of a tracking system operating in the same frequency band.

In addition, amplitude modulation added to the received signal to allow tracking can sometimes become a major handicap when the antenna system lags the target. This is a likely scenario in most overhead pass situations where up to 8.0 dB modulation can be experienced with as little as a 1.0 beamwidth lag.

Furthermore, up to now, conical scanners have been incapable of high scan rates and of scan rate agility. These features, sometimes desirable because of the nature of the mission, have always been a unique domain of single channel monopulse feeds.

The DECS\(^1\) tracking feed system described in this paper is a novel implementation of the conical scanner technology. It introduces remedies to performance shortcomings of currently available tracking feed systems and it provides solutions to operational problems endemic to these same systems. One feature allows higher efficiency operation in broadband frequency applications by providing an adjustable crossover level, a second feature allows operation as a steerable beam antenna system, a third feature provides for operation at high scan rates with the ability to vary the scan rate over a wide frequency range, a fourth feature allows generation of a stable reference

\(^1\) Patent Pending
coordinate system independent of the orientation of the feed to minimize crosstalk or to provide compatibility with non-orthogonal axes tracking systems.

**DECS TRACKING FEED SYSTEM**

The DECS tracking feed system consists of two major assemblies: the feed assembly mounted at the focal point of the reflector and the feed controller assembly collocated with the antenna control unit.

**FEED ASSEMBLY**

The primary functions of the feed assembly are to illuminate the reflector in the receive and/or the transmit mode and to generate the amplitude modulation needed for implementation of the autotrack function. As such the DECS feed basically operates as a typical conical scanner with a rotating offset aperture. However, its design is entirely different from that of a conventional conical scanner in the way the aperture offset can be changed, in the manner the aperture is rotated or positioned at any angular location and in the fashion the axes reference signals are generated.

This new design, shown in figure 1.0, is centered about a stationary coaxial-to-cylindrical waveguide adapter and a rotating radiating aperture which is essentially limited to the offset section of the waveguide. This is in sharp contrast to the design of a typical conical scanner in which the rotating assembly includes not only the offset aperture but the nonoffset cylindrical waveguide, the RF choke section and the drive shaft.

**COAXIAL-TO-CYLINDRICAL WAVEGUIDE ADAPTER**

The coaxial-to-cylindrical waveguide adapter consists of a stationary cylindrical waveguide section fed by a pair of crossed dipoles at one end and fitted with a RF choke section at the other end. The diameter of the waveguide section is selected to keep the TE11 mode cutoff frequency below the lowest frequency of operation. Its length is determined by the size of the dipoles and the length of the higher order mode suppressor element used. The type of dipole elements is dictated by the specific application and it varies with frequency, frequency bandwidth and transmitter power. Regardless of which type of dipole is selected their ground is hardwired to the waveguide end plate.

The RF choke section uses well behaved loaded sections of coaxial lines to present a modulation free impedance at the interface gap between the waveguide adapter and
the radiating aperture. It is designed to handle any power levels encountered in feeds of this nature.

It is interesting to note that, with this design, residual amplitude modulation is nonexistent. This type of modulation, traceable to modulation of the dipole input impedance, is generally caused by any asymmetry in the rotating conical scanner structure or in the RF choke section. A secondary function of the coaxial-to-waveguide adapter is to support the RF housing assembly located immediately behind the waveguide end plate. The RF housing serves as:

1. a housing for the various RF components such as 90 degree hybrid, bandpass filter(s) and low noise preamplifier(s) which are specified for each RF system configuration,

2. a housing for the servo amplifier needed to drive the aperture drive motor,

3. a mounting platform for other special purpose antennas such as low gain acquisition aid antennas or sidelobe comparison units,

4. a mechanical interface between the feed assembly and the antenna spars.

**RADIATING APERTURE**

The second component of the feed assembly is the rotating radiating aperture assembly which consists of an offset horn assembly and a drive mechanism.

Electrically the horn assembly is designed to provide a perfect match for the waveguide-to-cylindrical waveguide adapter and to illuminate the reflector in such a way as to produce an adjustable offset secondary beam. RF coupling is through the choke section described earlier and the offset adjustment is achieved with the use of a four section offset ring providing a total of three different offset values. Adjustment of the offset is performed at the horn itself and requires removal of the radome.

In a typical application in the 1435 to 2400 MHz band these values would be .70", .60" and .50" yielding a constant .25 dB crossover loss. This latter setting is of special interest for "SGLS" applications since it allows a net gain increase of .50 dB at S-Band for tracking and reduces the crossover loss to less than .15 dB in the transmit band from 1750 to 1850 MHz.
The approach to the mechanical design of the horn is entirely dominated by the low inertia and high rotational velocity requirements and is compatible with the 24,000 RPM goal set for this scanner. The waveguide section of the horn is a thin wall electroplated cylinder encased in an ultralightweight honeycomb support structure. The outer surface of the structure is solid and concentric with that of the waveguide adapter to reduce drag. The entire rotating mass is supported on a self lubricated air bearing and is capable of sustained velocities in a harsh environment.

The motor/tachometer assembly is a special design unit using a brushless DC motor powered by a pulse width modulation amplifier. It drives the horn according to the position, scan rate or swept scan rate scenario commanded by the feed controller. An optical encoder mounted next to the motor/tach assembly provides position information with a resolution of 1.25 degrees and closes the loop with the feed controller.

FEED CONTROLLER

The feed controller is a PC-based unit which incorporates the functions required to control the feed assembly and the displays needed to monitor its operation. It also provides the computational power needed to take full advantage of the high data rate gathering capability of the feed and allow digital signal processing using a technique similar to that described in reference (4).

The feed controller can be configured as a stand alone unit collocated with the antenna control unit or it can be integrated into any compatible antenna control unit.

In addition to the standard autotrack mode the controller features the following:

1. Beam Steering-Stationary
   This mode is used to statically position the beam of the antenna at any of 144 equally spaced points about its axis. Up to ten "designate" points can be stored in memory and selected by the operator at any time during operation. While in this mode the coordinates of the "designate" point currently activated are displayed on the screen.

2. Beam Steering-Program
   In this mode the beam of the antenna is steered by the controller according to computer generated commands tailored for specific mission. One such scenario would involve a near zenith pass during which autotrack operation would be temporarily suspended, predicted trajectory program track would be enabled and
the beam steering program would be used to maximize receive and/or transmit signals.

3. Scan Rate-CW
This mode is used to set the scan rate at any value within the allowable range of operation. The desired rate can entered by the operator, can be reached by use of the up/down arrow key or can be automatically selected according to preset routine(s) stored in memory. The actual scan rate is displayed on the screen.

4. Scan Rate-Swept Frequency
This mode is used to generate swept scan rates. The sweeping function is a triangular function with adjustable center frequency, sweep width and sweep rate. Its parameters are either determined by the operator or automatically selected according to preset routine(s) stored in memory. An X-Y diagram is used to display actual instantaneous scan rate as a function of time.

5. Stabilized Coordinate System
This mode is used to generate a stabilized coordinate system for the demodulator circuit and provide azimuth and elevation error signals independent of the axial orientation of the feed. This feature allows manual minimization of crosstalk in tracking systems using conventional mounts. It is also highly desirable for tracking systems based on non-orthogonal axes positioners in which the antenna itself rotates about its axis.

CONCLUSION

The DECS tracking feed system design, both hardware and software, is modular in nature and as such lends itself to actual implementation of all or some of the features described in this paper. In its simplest form without the adjustable beam offset and the high velocity capability it still provides significant performance improvements in the areas of cost, insertion loss, crosstalk minimization and residual noise modulation. In its "overhead pass" configuration, it provides, in addition to the above, a technique to optimize gain near zenith and minimize modulation in the transmit channel if applicable. As a high velocity scanner it allows a wide range of scan rates in the CW or the Swept Frequency modes.

All in all this feed system adds to the performance of the conventional conical scanner and, in time, will undoubtedly contribute to the large body of experimental data supporting the various claims of superior performance by the conical scanner feed technology over that of the single channel monopulse system.
REFERENCES


