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SLIP RINGS AND TWIST CAPSULES For E-O SENSOR SYSTEMS

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ABSTRACT

The dramatic increase in numbers and sophistication of electro-optic sensor systems has led to major developments in the hardware that is associated with this technology. Moog Components Group (MCG) has supported EO system development with improvements in slip rings, twist capsules, fiber optic rotary joints and multiplexing technologies. MCG has participated in the development of many of the major airborne and ground based EO systems and this Application Note is intended to outline this experience and heritage as well as provide a brief overview of the technologies available to EO designers for transferring data and power across rotating interfaces.

DESCRIPTION

Electro-Optic sensors or sensor suites are normally housed in a gimbaled assembly. These systems are typically scanning systems and require the transmission of power and data to and from the scanning sensor(s).

Figure 1: Typical Gimbaled EO System

This transmission is accomplished by a slip ring in the case of continuous rotation or a twist capsule in the case of limited rotation. The most common configuration is a slip ring on the azimuth or roll axis where continuous rotation is often desired, and a twist capsule on the elevation, pitch, or yaw axes where limited rotation is sufficient.

Slip Rings: Slip ring assemblies provide the functionality of a continuously rotating electrical interface. These assemblies contain discrete noble metal rings for each electrical circuit and corresponding sliding wipers (or brushes) to conduct the power and signals from the rotating rings to the stationary member (Figure 2). The slip rings used for the sensor gimbals typically require very dense circuit packaging to meet very stringent size requirements. The most slip ring requirements for slip rings in EO applications have developed around the need to transmit high speed digital data for FLIR and day video.

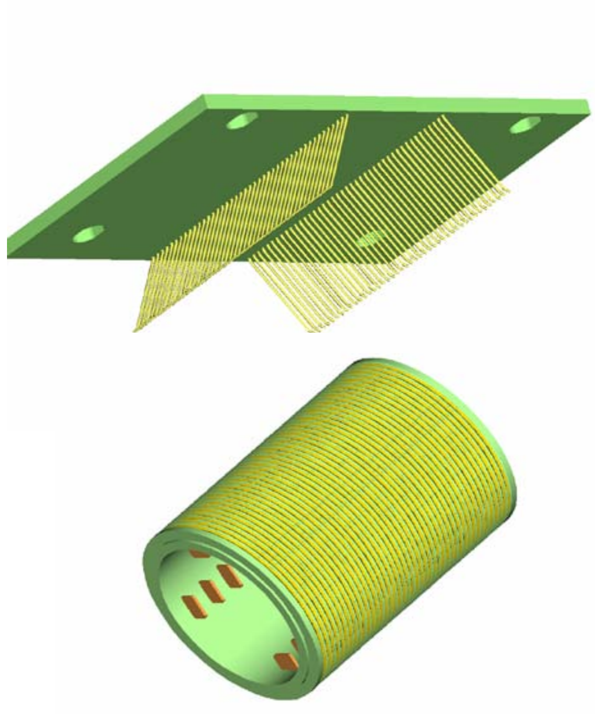

Figure 2: Noble metal ring and brush construction

Twist Capsules: In most cases gimbaled EO systems require continuous, unlimited rotation on just one axis, typically the azimuth or roll axis. Normally the other axes (pitch, elevation, or yaw), require only limited rotation, i.e., less than 360 degrees. This allows the use of a twist capsule, or Poly-Twist, to transmit electrical power and signals. By the use of wrapping flexible circuits, the twist capsule designer is able to increase circuit density, decrease weight, and improve system reliability over traditional cable wraps. The long life, low and consistent torque, and the small size make twist capsules the best solution for scanning, or limited rotation axes in EO systems.

Figure 3: Wrapping Flexible Circuits of a Twist Capsule

The stress on the flexible circuit is well below its endurance stress limit producing very low torque levels and very long operational life. A twist capsule is frequently used as a substitute for a cable wrap providing a very size and weight efficient alternative. In addition the reproducible and dependable torque characteristics of a twist capsule result improved servo control on the selected axis.

Controlled impedance flex tape lines can be used to control impedance on video and high speed data lines. Coaxial cables and optical fibers can be integrated into the design in special cases. This allows the transmission of high speed digital data on both optical and copper media.

Figure 4: Harnessed Twist Capsule Assembly

<u>Fiber Optic Rotary Joints (FORJ)</u>: In the case of systems that utilize optical fiber to carry high-speed data, the most straightforward rotational interface is a passive fiber optic rotary joint (FORJ). These devices are characterized by the numbers of optical fibers that are carried through on discrete physical fibers (passes) and by whether the fibers are single or multi-mode. For example, a single pass, multi-mode FORJ contains one discrete multi-mode fiber channel. These devices are bi-directional and their performance parameters are independent of the direction of the signal. The size of the single channel FORJ is quite small (see Figure 5) with the length of less than 15 mm and the diameter

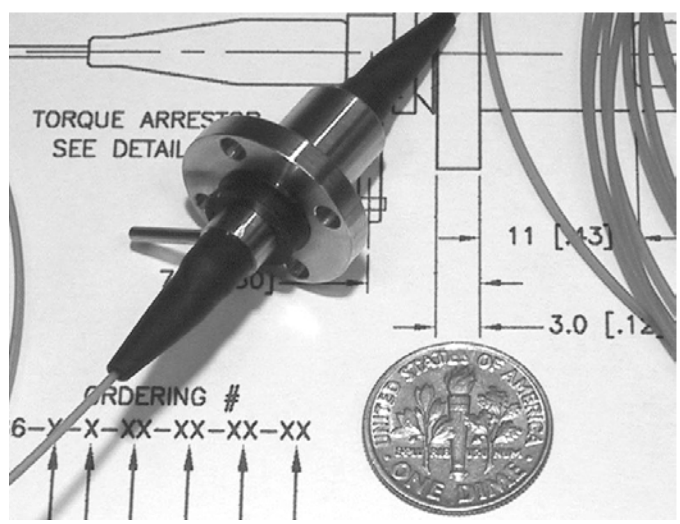

Figure 5: Single channel FORJ

less than 10 mm. The environmental robustness of these devices has been well proven in military as well as harsh commercial marine environments.

The single and dual channel FORJ's are powerful tools for "futureproofing" any rotary data interface. These simple and compact devices provide a data bus for data at speeds of well over 20 Gbps, allowing a convenient upgrade path for years to come. Although FORJ technology exists for 3 or more optical channels, the size of these devices preclude their use in most EO gimbals.

As sensor systems become more sophisticated and the digital battlefield continues to push for greater information density, system architects are starting to view the rotational interface as a potential bottleneck for data flow. Of course not all network data must go onto these rotating platforms, but in most systems there must be data communication between the sensor and the main platform. The reader is referred to Moog Components Group Application Note 204 on High Speed Data for a more detailed discussion of the high speed data options available for these systems.

GROUND BASED SENSORS

The best example of ground based EO systems supported by Moog is the Abrams Tank Commander's Independent Thermal Viewer (CITV). The CITV has used an MCG slip ring assembly to allow continuous rotation on the azimuth axes since the program's inception in the late 1980's. A number of slip ring upgrades has allowed system improvements over the 15+ years of this program. The Bradley armored vehicle uses Moog's slip ring on the azimuth axis of it's Commander's Independent Viewer (CIV) and a twist capsule on the elevation axis.

Figure 6: Slip Ring used in Military Vehicle Commander's Viewer (CITV)

Requirements for EO sensors are especially critical in Unmanned Ground Vehicles (UGV) since these systems must incorporate driver replacement sensors. The US Army Tank and Automotive Research, Development and Engineering Center (TARDEC) outlines the sensor systems required for Unmanned Ground Vehicle (UGV) technology as shown in Table 1. These sensor systems normally require some power, but the video and data requirements are typically the significant design feature due to the data requirements of the sensor detectors or detector arrays. These detectors often need cooling fluid and the systems need precise positional information, therefore the rotary interface often includes fluid rotary unions and rotary position feedback devices.

TABLE 1: Unmanned Ground Vehicle (UGV) Sensor Systems

Function	Sensors
Mobility	Day/night stereo vision; Scanning laser range-finder; Two radar systems (4GHz radar to penetrate vegetation, and 77 GHz radar for imaging obstacles at longer ranges)
Traffacability	Multi-spectral imager Polarizing imager Small ultrasonic sensors (for close-in safeguarding functions)
RSTA* mission module	TV camera High resolution forward-looking infrared (FLIR) sensor; Laser range-finder/designator; An array of acoustic sensors
Other configurable mission modules	Undefined

** Reconnaissance, Surveillance, and Target Acquistion*

The chart in Table 2 below shows the major production armored vehicle EO systems for which Moog produces slip rings or twist capsules.

Table 2: MCG Production Armored Vehicle Thermal Viewer Programs

Bradley CIV	Slip Ring and Twist Capsule
Abrams CITV	Slip Ring
Stryker MGS Thermal Viewer	Slip Ring
SGTS/ KEOTS	Slip Ring
VBCI--Sagem MPS (Multi Purpose Sight)	Slip Ring
Korean K-1	Twist Capsule
Lemur Sight	Slip Ring

AIRBORNE SYSTEMS

Moog Components Group's slip rings and twist capsules are used extensively in airborne EO systems. The latest upgrade to the F-18 Hornet's EO targeting pod, ATFLIR, utilizes a Moog slip ring to allow continuous rotation in the roll axis and a twist capsule for scanning, or limited rotation, in the elevation and yaw axes. The LANTIRN and its successor Sniper used for EO targeting and navigation on the F-16 uses Moog slip rings and twist capsules exclusively. The Predator UAV, LAMPS helicopter, and Apache helicopter all "see in the dark" using Moog Components Group slip ring and twist capsules. Table 3 shows just some of the E-O systems that contain Moog Components Group slip rings and twist capsules.

Low Profile Azimuth Slip Rings

System height is often the primary concern of the EO gimbal designer. Moog Components Group has the solution with its patented broadband platter slip ring design. This broadband technology allows the slip ring designer to package multiple high speed data lines on slip ring platters, and then "stack" these platters with their accompanying brush blocks into a very low profile design. Power rings as well as discrete signals and video can also be placed on these slip ring platters. This has led to a dramatic decrease in typical slip ring height or length over traditional slip ring "drum-style" designs.

Table 3: AIRBORNE E-O SYSTEM HARDWARE

Lamps Helicopter FLIR (AN/AAQ-27)	Slip Ring, Twist Capsules
Night Hawk FLIR AN/AAS-38	Twist Capsules
AN/AAQ-26 FLIR (AC 130)	Slip Ring, Twist Capsule
ATIRCM (Infrared Countermeasure)	Slip Ring, Twist Capsules
LANTIRN AN/AAQ-13 and AN/AAQ-14	Slip Ring, Twist Capsules
Sniper (AN/AAQ-38)	Slip Ring, Twist Capsules
Apache Arrowhead	Twist Capsules
F117 IRADS	Twist Capsules
ATFLIR (AN/ASQ-228) Pod	Slip Ring, Twist Capsule
Predator MTS (Multi-Spectral Targeting System) AN/AAS 52	Slip Ring, Twist Capsule
IFTS (AN/AAQ-32)	Slip ring
AN/AAQ 15/17	Twist Capsules
SAFIRE NTIS (AN/AAQ 22)	Slip Ring
Multi-Sensor Turret AN/AAQ 35	Slip Ring
F35 (JSF) EOTS	Slip Ring
ASELFLIR 200	Slip Ring and Twist Capsules

High Speed Data

The dramatic improvement in image definition, the use of multi-sensors, and increased communication requirements have driven the need for EO Systems to significantly increase transmission speeds of data channels with every generation of upgrade. MCG has produced EO slip rings and twist capsules that handle as many as two dozen data channels at over 400 Mbps each, for an aggregate bandwidth of 12 Gpbs. Slip ring/fiber optic rotary joint hybrid designs contain both copper lines for power and signals, as well as fiber lines for fiber optic signals.

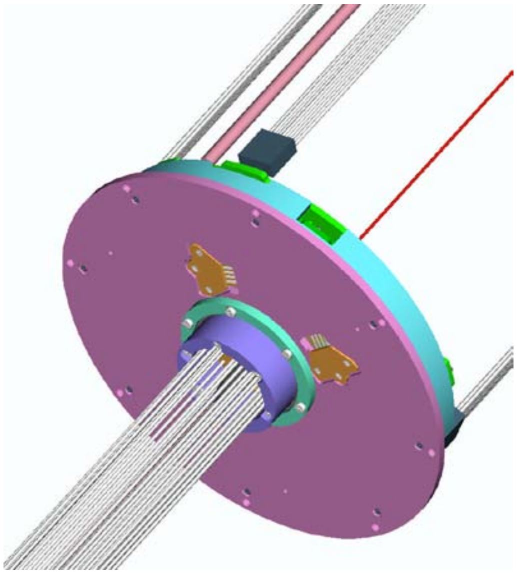

Figure 7: Example of Low Profile, Platter Slip Ring

Design and manufacturing techniques have been developed and patented that increase signal bandwidth while controlling crosstalk and EMI/EMC. A range of solutions is available to handle data channels such as GigE, Fibre Channel, and IEEE1394 to name just a few. These high speed data solutions are being used in existing EO systems.