RF ROTARY JOINTS FOR SPACE PROGRAMS

As the demand for more sophisticated sensors and equipment on satellites continues to increase, the need for rotational antennas for space-based radar and communication systems continues to expand; whether used for commercial, science or military applications.

A critical key component in these complex space antenna systems is an RF rotary joint. These components are used to assist in the transmitting and receiving of RF power and data through the rotational interface within the antenna/gimbal subsystem.

While RF rotary joints have been used for over 75 years for ground based, shipboard, and airborne rotating radar and communication subsystems they were rarely used for space applications.

This industry misconception was based on the belief that rotary joints were unreliable for space-based applications. The primary reasons were two-fold. First was that the bearing lubricant could prematurely fail or migrate into the RF path, resulting in degraded operation or failure. Utilizing established methods of analysis and proper bearing and lubrication selection has proven this to be false. Second, it was felt that either a cable wrap or flexible waveguide could do the job at a lower cost. After some very expensive qualification failures of cable wraps and flexible waveguide, customers now understand that rotary joints are not only more reliable but can offer improved performance. RF rotary joints are now commonly used in space applications.

Diamond Antenna and Microwave Corporation has been supplying space qualified RF rotary joints since the onset of rotational requirements on satellites and has recently invested significantly in additional personnel and equipment in order to keep pace with this growth. Diamond is now the world's foremost supplier of rotary joints for use in space.

All RF rotary joints, regardless of the application, are designed to operate throughout a defined lifetime, while subjected to various environmental & dynamic conditions. The one major difference in dealing with a space program is clear - after launch, the product **must be 100% reliable**, as it can't return for refurbishment or repair.

Design:

In order to assure this critical reliability, all space designs at Diamond Antenna go through extensive reviews and design process steps. Diamond has an extensive heritage of proven space rotary joints and over 2000 terrestrial RF rotary joint designs to leverage. Most applications are unique, leading to many modified or customized units to support customer requirements.

Specification Review:

It all starts with a complete review of customer and specific industry documents. While all Diamond customers have specifications that must be followed, the space industry has some of the most stringent and numerous. It is not unusual that dozens of specifications regarding material selection, structural factors, thermal control and quality requirements apply to a specific space application. Diamonds' team works closely with customer representatives to assure a complete understanding and agreement of the requirements has been reached.

RF Design:

After the specification review, a suitable design approach is established to satisfy all RF and mechanical requirements. For the RF design, Diamond utilizes several software packages to analyze the initial design, including CST Microwave Studio, Solidworks and various home-grown tools. ORBIS and ANSYS. During this phase, all S-Parameters of the RF design are simulated. Additional analyses may also be performed, depending on the program requirements including for example, analysis of high power thermal rise, corona prediction, RF change vs. temperature, multipaction and RF change due to dimensional tolerance.

Mechanical Design:

For the mechanical design, a complete structural analysis must be performed to assure positive margins of safety are seen during launch, satellite separation and other flight maneuvers. These dynamic environments will be simulated via qualification and validated during flight testing later in the program.

Most rotary joints used in space are non-contacting. This means there are no contacting internal parts, except for the bearings. This increases overall reliability by avoiding any wear and debris generation that can degrade performance over the mission.

The bearings used in space designs are a critical factor when it comes to life & reliability. The ability of the bearings to survive years of operation in severe environments is crucial and requires detailed analyses to be performed. This involves extracting vibration & shock loads from a structural analysis and then calculating bearing stress levels, L_{10} & L_{01} life and determining various margins of safety.

Equally as critical as the bearing type selection is the choice of a lubricant. The selection must provide adequate lubrication throughout the mission lifetime, while being subjected to shock, vibration, operating loads and thermal conditions with temperature extremes as high as +300^{o} C and as low as -150^{o} C. In addition, the lubricated bearing cannot cause excessive torque values during the products' rotation. To determine this, a torque and lubricant loss analyses are performed.

In some applications Diamond can supply a rotary joint consisting of a rotor and stator assembly utilizing the customer gimbal bearings.

SDRL's:

A significant portion of space program activity centers around review meetings & documentation, Supplier Data and Requirements List (SDRL's)

Typical meetings include a post-award Kickoff Meeting, followed by a Preliminary Design Review, Critical Design Review, Manufacturing Readiness Review, Test Readiness Review, and finally a Pre-Ship Review. During the meetings, reviews of the various analyses & other program documentation occurs to ensure all parties understand the design, manufacturing and test approach.

Other SDRL requirements focus on Product Assurance, Assembly/Test Procedures, Schedule, Risk Mitigation, Parts, Materials and End Item Data Packages.

Production:

Each customer has varied sets of requirements, including some that have process controls that must be followed 100% of the time. The one that is common for all is cleanliness. All parts are specifically cleaned prior to assembly and kept this way until shipment. Any contamination or debris can cause mission failure. All processing and assembly is performed within at least a Class 10,000 clean room, with critical operations performed in a Class 100 clean environment. Personnel are trained to properly dress and operate in these conditions.

(RF Testing in Clean Room)

Some customers require portions of the assembly and test to be performed in their own facilities. In this case the parts, test equipment and personnel travel to the customers' site, performing the required activity with customer QA witnessing.

Testing:

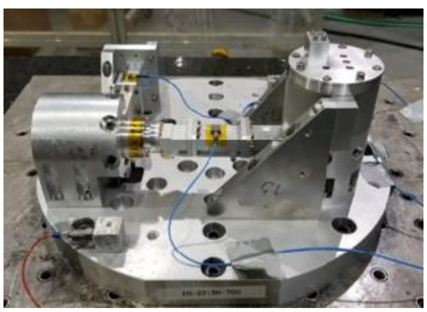
After required processing has been completed, the products' operation and reliability must be completely verified. During the performance of any new program, verification is accomplished by undergoing qualification testing.

The scope of qualification testing depends on the specific program, the scope of the design changes from legacy products and ultimately documented in a customer approved qualification test procedure. While no two projects are identical, a common qualification program may consist of the below.

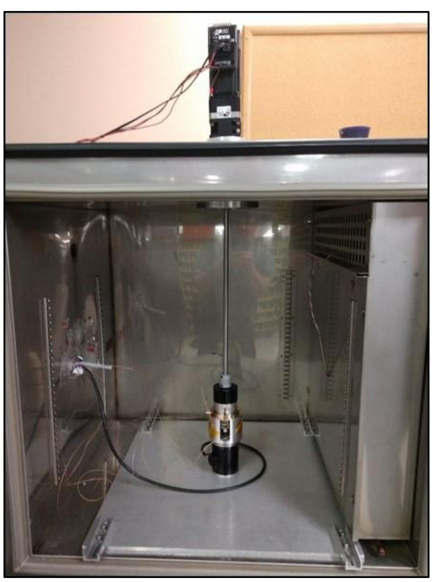
RF Acceptance
Mechanical Acceptance
Dimensional Inspection
Torque
Sine Vibration
Random Vibration
Shock
Thermal Vacuum
Thermal Cycling
Thermal RF
Life Testing

After the completion of successful qualification testing, the flight hardware is manufactured. While qualification testing verified the unit's performance, flight units are typically put through a similar, but less stressful, test program. Flight tests are typically performed at slightly lower thermal and dynamic levels when compared to the original qualification testing.

Typical Test Setups:



(Vibration)



(Thermal Torque)

(Thermal Vacuum)

To support the continued growth of space rotary joint products, Diamond has invested in tools, fixtures, test equipment, additional laminar flow benches and a state-of-the-art thermal vacuum test chamber.

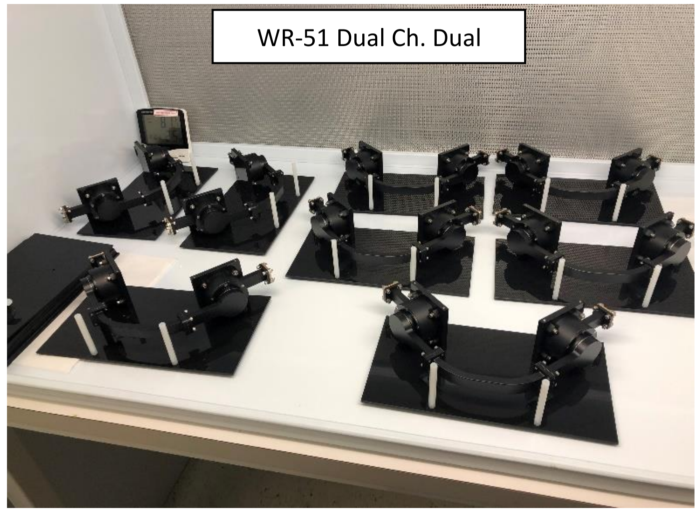
(Thermal Vacuum Test Chamber)

2020 & Beyond:

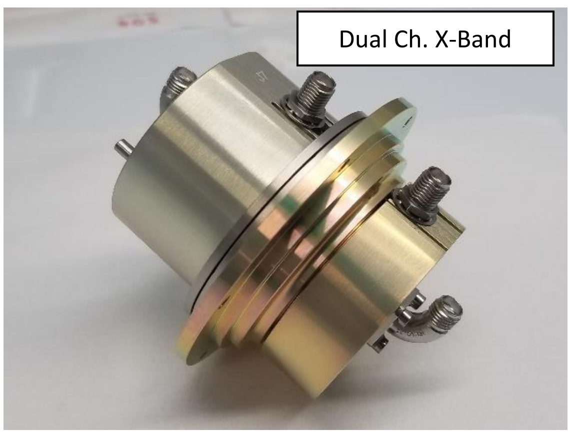
As a result of providing high quality and reliable space products, coupled with exceptional customer service, Diamond will remain positioned to support current and future demand for critical space qualified RF rotary joints used by customers around the world.

Wide Design Variety:

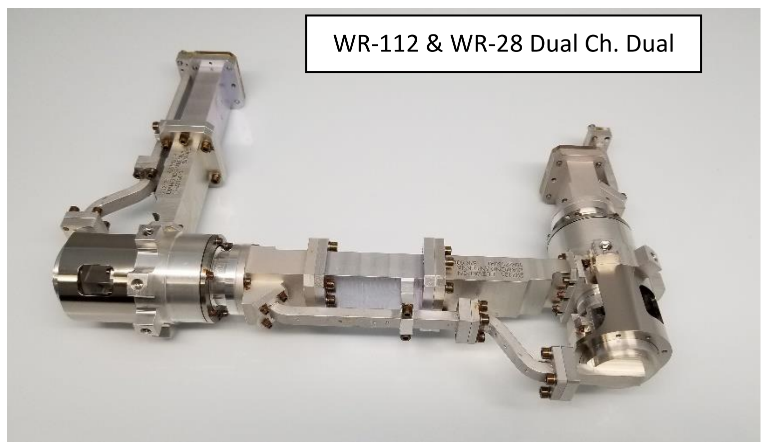
WR-34 Dual Ch. Dual Axis



WR-51 Dual Ch. Dual

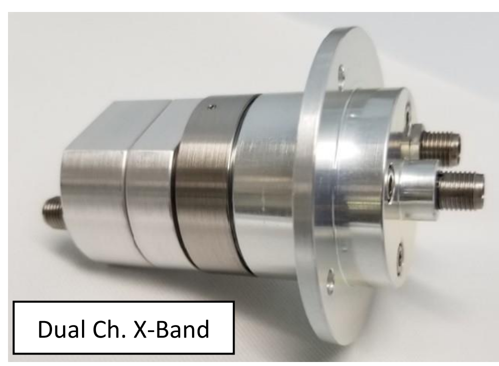


Dual Ch. X-Band



WR-112 & WR-28 Dual Ch. Dual

Single Ch. WR-34



Dual Ch. X-Band

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