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ROTARY JOINTS – GLOSSARY

1 Purpose and Background

This document compiles the technical terms used by SPINNER in its product data sheets and other technical documents concerning rotary joints. Wherever possible we provided rigorous definitions of the terms.

The task of a rotary joint is to enable low-loss transmission of electrical and optical signals between a static and a rotating part. Electrical power and media can also be transmitted if necessary. Rotary joints may also be equipped with further subsystems like angular encoders and revolution counters.

SPINNER's design capabilities include systems for data, power and media transmission as well as radio frequency (RF) signals.

2 General Terms

Rotary joint	A rotary transition featuring an unlimited angle of rotation. Commonly a rotary joint is abbreviated as RJ or R/J, in case of fiber optical rotary joint as FORJ.
Swivel joint	Any rotary transition featuring a limited angle of rotation.
Channel	Describes a physical transmission path having one port on the stator and one port on the rotor. Unlike in telecommunication engineering, this term does not describe a certain limited portion of the electro-magnetic spectrum when used in this context.
Module	A basic element of a rotary joint which often covers a single transmission channel. Multichannel designs are commonly comprised of several independent modules.
Hollow-shaft module	A module with a clear inner bore along its axis of rotation. Usually hollow-shaft modules are stackable to create multichannel rotary joints. In that case the inner transmission lines of all neighboring modules are fed through the center bore.
On-axis module (center module)	A module without a center bore. Commonly used as the final stacking element in multichannel units.
Stator	Static portion of a rotary joint. A stator is not necessarily characterized by the presence of a mounting flange.
Rotor	Rotating portion of a rotary joint. A rotor is not necessarily characterized by the absence of a mounting flange.
Rotational gap	Necessary mechanical gap which separates stator and rotor.
Rotational angle	Angle θ between rotor and stator.
Contacting rotary joint	A rotary joint utilizing galvanic sliding contacts. Typically, wide-band designs are based on contacting coupling structures. Furthermore, contacting designs allow for DC transmission and can handle low frequency signals at limited space. Operational life is limited however (usually to some 10^6 to 10^7 revolutions) because of contact wear.

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<p>Non-contacting rotary joint</p>	<p>A rotary joint based on non-contacting coupling mechanisms like capacitive, inductive, transmission line or transformer coupling.</p> <p>Non-contacting rotary joints generally cover a limited bandwidth (typical relative bandwidth less than 40%; in most applications some 10 to 20%) because of frequency-dependent coupling mechanisms. Non-contacting rotary joints offer superior product life time over contacting designs since contact wear is eliminated. Typical life figures are only limited by the bearing or sealing system and might be as high as several hundred millions of revolutions.</p> <p>The transmission line coupling mechanism is usually limited to channels operating in the GHz frequency range because lower frequencies would result in large coupling structures.</p>
<p>Slip ring</p>	<p>A particular variant of a contacting low frequency rotary joint, mostly equipped with a large-diameter center bore.</p> <p>Slip rings are based on ring and static brush systems and commonly used for power and signal transmission. Slip ring assemblies for big multichannel rotary joints may feature some 100 ways and are often used to accommodate the (smaller) RF subsystems which are nested inside the slip ring's center bore.</p>
<p>Fiber optic rotary joint</p>	<p>A fiber optic rotary joint (FORJ) is the optical equivalent of an RF rotary joint or an electrical slip ring. It allows the transmission of an optical signal while rotating.</p> <p>Single channel and multichannel FORJs are available with both single- and multimode fiber types.</p>
<p>Maximum and minimum values</p>	<p>Maximum or minimum values represent guaranteed limit values which are not exceeded at any time or under any condition specified in the data sheet.</p> <p>Usually there is a safety margin between these guaranteed maximum limits and the values measured at room temperature.</p>
<p>Typical values</p>	<p>In many cases SPINNER specifies both maximum and typical values.</p> <p>Typical values are given whenever useful for a more realistic description of the performance. These values are typically observed on the majority of a production batch when measured at room temperature. SPINNER does not guarantee these "typical values" however.</p>

RF port numbering	<p>In order to define the scattering matrix of a rotary joint a non-ambiguous designation of the RF ports is required. If not otherwise defined SPINNER uses the following RF port numbering convention for its documents (e.g. data sheets, interface control drawings, qualification test procedures and records, acceptance test procedures and records):</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Channel number</th> <th>Port number on labeled* part</th> <th>Port number on unlabeled* part</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>1</td> <td>2</td> </tr> <tr> <td>2</td> <td>3</td> <td>4</td> </tr> <tr> <td>...</td> <td>...</td> <td>...</td> </tr> <tr> <td><i>i</i></td> <td><i>2i-1</i></td> <td><i>2i</i></td> </tr> </tbody> </table> <p>Following this convention the scattering matrix [S] of a <i>n</i>-channel rotary joint can be written as</p> $[S] = \begin{bmatrix} S_{1,1} & S_{1,2} & \dots & S_{1,2n-1} & S_{1,2n} \\ S_{2,1} & S_{2,2} & \dots & S_{2,2n-1} & S_{2,2n} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ S_{2n-1,1} & S_{2n-1,2} & \dots & S_{2n-1,2n-1} & S_{2n-1,2n} \\ S_{2n,1} & S_{2n,2} & \dots & S_{2n,2n-1} & S_{2n,2n} \end{bmatrix} \xrightarrow{\text{ideal** case}} \begin{bmatrix} 0 & 1 & \dots & 0 & 0 \\ 1 & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \dots & 0 & 1 \\ 0 & 0 & \dots & 1 & 0 \end{bmatrix}$ <p>* Rotary joints consist of a stator and a rotor which are rotating relatively to each other. One of these two parts is marked with the product number BN XXXXXX, this is called the "labeled" part. The other part is called "unlabeled".</p> <p>** "Ideal" in this context means: impedance-matched, lossless, fully decoupled, electrical length negligible.</p>	Channel number	Port number on labeled* part	Port number on unlabeled* part	1	1	2	2	3	4	<i>i</i>	<i>2i-1</i>	<i>2i</i>
Channel number	Port number on labeled* part	Port number on unlabeled* part														
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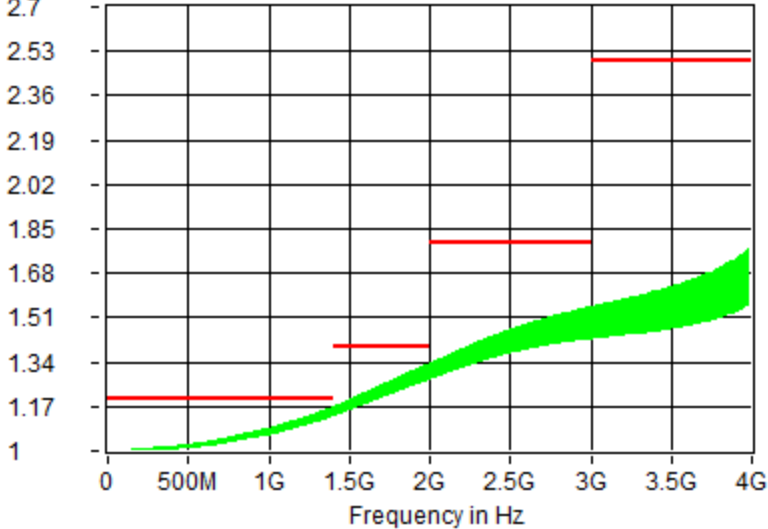
3 Radio Frequency Characteristics

Interface type	<p>Generally, SPINNER RF rotary joints come with either waveguide or coaxial ports.</p> <p>The appropriate choice depends on application, frequency range and power rating requirements. Most waveguide rotary joints feature standardized waveguide interfaces according to IEC-154, MIL-DTL-3922 or EIA-RS 271, which may be either of the plain or choke type. Grooves on sealed flanges in combination with gaskets allow for pressurization and provide protection against ingress of dirt and moisture. Internal corners of waveguide interfaces are sometimes rounded for manufacturing reasons. These rounded corners have been designed carefully and thus are fully electrically compensated when mated to "real" rectangular standard waveguides. Consequently, RF performance will not be compromised at all by the rounding. Coaxial designs are usually equipped with precision coaxial connectors according to IEEE Std. 287-2007.</p>
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<p>Interface orientation</p>	<p>Describes the basic style of a rotary joint depending on the orientation of both interfaces (rotor and stator).</p> <p>Several waveguide designs may actually only be realized as "U" styles and must be adapted to the desired style using external waveguides.</p> <p>"I"- style: Both interfaces in line with the rotational axis. "U"- style: Both interfaces perpendicular to the rotational axis. "L"-style: One interface is perpendicular to the rotational axis, the other interface is in line with the rotating axis.</p>
<p>Frequency range</p>	<p>Portion of the electromagnetic spectrum which a component has been designed for and within which the respective specification is valid.</p> <p>SPINNER offers designs for the entire frequency range between DC and the millimeter wave range.</p> <p>In the following the frequency range will be referred to as <i>FR</i>.</p>
<p>Peak power capability</p>	<p>Maximum permissible short term power which a component can handle safely without internal arcing or breakdown.</p> <p>In contrast to "instantaneous values", this term refers to short-term RMS values within the pulse duration. Usual pulse durations are in the μs range. It should be pointed out that the actual peak power capability depends considerably on parameters such as absolute air pressure inside the component, load VSWR, temperature, pulse duration and pulse repetition frequency. Specifying the required operating pressure for a given peak power is of paramount importance. While low ambient air pressure will degrade the peak power capability, it can be massively enhanced by a pressurization of all electrically stressed components with dry compressed air or particular insulation gases like SF₆. If space use is intended, a different vacuum discharge mechanism called "multipactor discharge" becomes crucial. SPINNER datasheets provide all necessary information about these limiting conditions.</p> <p>Depending on the connector size, coaxial rotary joints usually feature peak power figures in the 1 to 10 kW range while typical values for unpressurized waveguide rotary joints might be as high as 10 kW to 1 MW (also depending on waveguide size).</p> <p>Peak power capability is limited to the air pressure at sea level unless otherwise noted.</p>
<p>Average power capability</p>	<p>Maximum permissible long term ("continuous wave" or CW) power which a component can handle safely without internal overheating.</p> <p>During operation Ohmic and dielectric losses generate heat inside the rotary joint. Hence, the maximum permissible average power is frequency-dependent.</p> <p>The relation between heat generation and heat dissipation (by metallic feeder waveguides, casing, mounting flanges and air convection) determines the actual CW power that may be applied over a long period of time while still ensuring safe internal operating temperatures for all critical parts. Average power handling may be increased by additional forced cooling (air or water) and use of advanced materials or designs. Excessive ambient temperatures will degrade the average power capability respectively.</p>

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<p>VSWR</p>	<p>"Voltage Standing Wave Ratio", an expression for the degree of wave reflection from a component due to impedance mismatch.</p> <p>Ideally, in the perfectly matched case there is no reflected wave and VSWR is equal to 1. It is infinite in the case of total reflection.</p> <p>High VSWR values are not desirable because they indicate a high percentage of reflected power and contribute to insertion loss. A high VSWR will also cause locally raised voltages due to standing waves and therefore compromise power handling.</p> <p>Often a tradeoff between VSWR and bandwidth has to be found. Usual VSWR values would range from 1.10 to 1.70. Specialized big center bore designs which must cover a very wide bandwidth cannot reach these values however.</p> <p>"VSWR, max.", as given in SPINNER data sheets, represents worst-case values that besides frequency response also include thermal and rotational effects.</p> $VSWR_{max} = \max_{f \in FR} \left\{ \max_{0^\circ \leq \theta < 360^\circ} \{VSWR(f, \theta)\} \right\}$ <p><u>Example:</u></p> <p>VSWR (S44), rotational angle varied</p> 
<p>Return loss</p>	<p>Alternative representation of VSWR, describes the logarithmic ratio (in dB) between incident power P_{in} and reflected power P_r at a component's port:</p> $a_r = 10 \text{ dB} \cdot \lg \frac{P_{in}}{P_r}$ <p>The return loss a_r is infinite in the perfectly matched case and zero at total reflection. A high return loss figure is desirable and indicates a well matched component. Return loss values usually range from 10 dB to 40 dB.</p>

VSWR variation over rotation

Sometimes also named "VSWR WOW", this parameter describes how much the VSWR changes over a full rotation at the "worst" frequency within the specified frequency range.

For this parameter several different definitions are in use. The most popular ones are the difference definition $\Delta VSWR$ and the ratio definition $VSWR_{ratio}$.

SPINNER generally adheres to the difference definition which expresses "VSWR variation over rotation, max." $\Delta VSWR_{max}$ as the difference between the maximum and minimum VSWR values measured at the frequency point f_{VSWRv} which features the highest VSWR variation over the rotational angle θ :

$$\Delta VSWR(f) = \max_{0^\circ \leq \theta < 360^\circ} \{VSWR(f, \theta)\} - \min_{0^\circ \leq \theta < 360^\circ} \{VSWR(f, \theta)\}$$

$$\Delta VSWR_{max} = \Delta VSWR(f_{VSWRv}) = \max_{f \in FR} \{\Delta VSWR(f)\}$$

For practical measurements the definition above is often approximated by the maximum distance between the two VSWR frequency response curves taken at the "worst" and the "best" rotational angle. Common values are between 0.02 and 0.2.

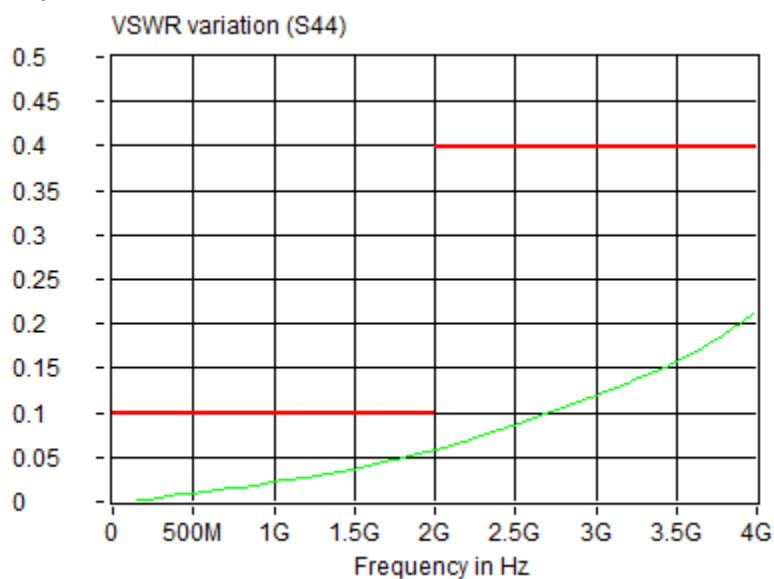
The other common definition, the ratio definition, is given by

$$VSWR_{ratio}(f) = \frac{\max_{0^\circ \leq \theta < 360^\circ} \{VSWR(f, \theta)\}}{\min_{0^\circ \leq \theta < 360^\circ} \{VSWR(f, \theta)\}}$$

$$VSWR_{ratio,max} = VSWR_{ratio}(f_{VSWRv}) = \max_{f \in FR} \{VSWR_{ratio}(f)\}$$

The ratio definition leads to values greater than one. SPINNER uses this definition only when it is explicitly required by a customer.

Example:



Insertion loss

The insertion loss (often abbreviated as IL) is the attenuation of a signal being passed through a device within the signal path. Insertion loss a_i is usually expressed as the logarithmic ratio (in dB) between incident power P_{in} and output power P_{out} :

$$a_i = 10 \text{ dB} \cdot \lg \frac{P_{in}}{P_{out}}$$

Internal transmission line structures, feeder waveguides or cables cause Ohmic, dielectric and reflection losses. The dissipated energy results in heat generation and limits the maximum permissible long-term power rating.

Generally speaking, long designs suffer from higher insertion loss than shorter ones and waveguide designs are usually superior to coaxial designs.

Whenever there is a choice, the system waveguide size should be chosen as big as possible because of increased waveguide losses in the lower portion of their operating band.

Insertion loss is somewhat temperature-dependent. SPINNER would like to point out that any insertion loss figures stated in SPINNER data sheets hold true for the entire specified range of operating temperatures and the nominal operating power.

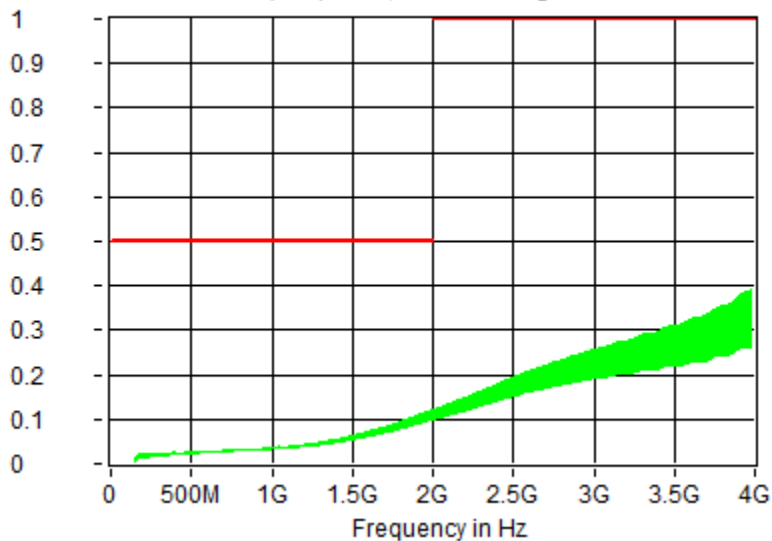
Most waveguide rotary joints feature insertion loss values in the 0.1 dB to 0.5 dB range, and so do usual coaxial designs without cables. Large multichannel rotary joints contain additional internal cables which may cause significant additional losses.

"Insertion loss, max.", as given in SPINNER data sheets, represents worst-case values that besides frequency response also include thermal and rotational effects.

$$a_{i,max} = \max_{f \in FR} \left\{ \max_{0^\circ \leq \theta < 360^\circ} \{a_i(f, \theta)\} \right\}$$

Example:

Insertion loss (S43) in dB, rotational angle varied



Insertion loss variation over rotation

Sometimes also named "insertion loss WOW", this parameter describes how much insertion loss changes over a full rotation at the "worst" frequency within the specified frequency range. For most technical applications this parameter is of higher relevance than VSWR variation over rotation.

"Insertion loss variation over rotation, max." $\Delta a_{i,max}$ is defined as the difference between the maximum and minimum insertion loss values measured at the frequency point f_{iLv} which features the highest insertion loss variation over the rotational angle θ :

$$\Delta a_i(f) = \max_{0^\circ \leq \theta < 360^\circ} \{a_i(f, \theta)\} - \min_{0^\circ \leq \theta < 360^\circ} \{a_i(f, \theta)\}$$

$$\Delta a_{i,max} = \Delta a_i(f_{iLv}) = \max_{f \in FR} \{\Delta a_i(f)\}$$

For practical measurements the definition above is often approximated by the maximum distance between the two insertion loss frequency response curves taken at the "worst" and the "best" rotational angle.

Insertion loss variation is mostly a footprint of VSWR variation which in turn causes varying reflection losses.

Any "insertion loss variation over rotation, max." figures given in SPINNER data sheets are worst-case values (usually between 0.05 dB and 0.2 dB) and do already include a safety margin to consider measurement instabilities and drift.

Example:



Phase variation over rotation

Phase variation over rotation or "phase WOW" describes how much the insertion phase of a rotary joint changes over a full rotation at the "worst" frequency within the specified frequency range.

This parameter indicates a variation of the effective electric length. Along with insertion loss variation over rotation it is of higher relevance for most technical applications than VSWR variation.

"Phase variation over rotation, max." $\Delta\varphi_{i,max}$ is defined as the difference between the maximum and minimum insertion phase values measured at the frequency point f_{Pv} which features the highest phase variation over the rotational angle θ :

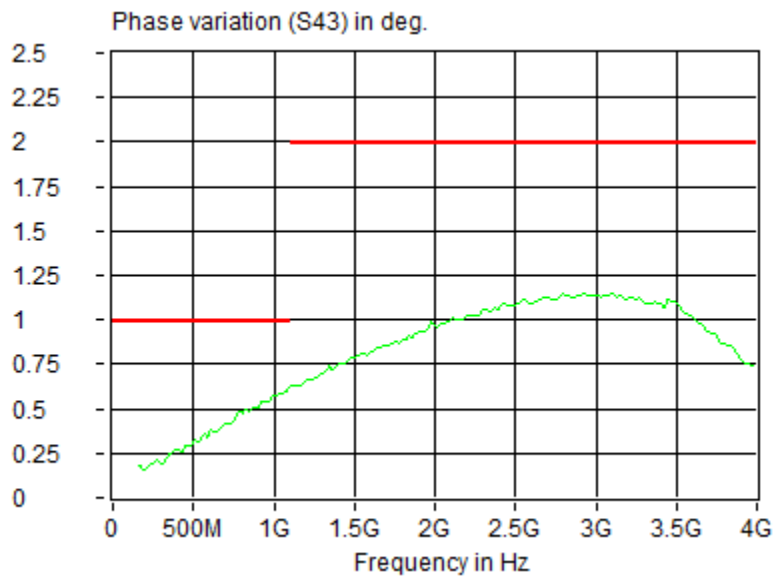
$$\Delta\varphi_i(f) = \max_{0^\circ \leq \theta < 360^\circ} \{\varphi_i(f, \theta)\} - \min_{0^\circ \leq \theta < 360^\circ} \{\varphi_i(f, \theta)\}$$

$$\Delta\varphi_{i,max} = \Delta\varphi_i(f_{Pv}) = \max_{f \in FR} \{\Delta\varphi_i(f)\}$$

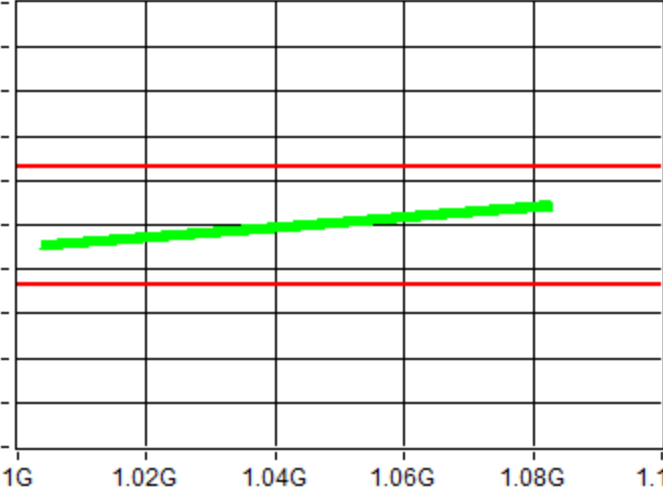
For practical measurements the definition above is often approximated by the maximum distance between the two insertion phase frequency response curves taken at the "worst" and the "best" rotational angle.

Any "phase variation over rotation, max." figures given in SPINNER data sheets are worst-case values (usually of the order of 0.5 to 5 degrees) and do already include a safety margin to consider measurement instabilities and drift.

Example:

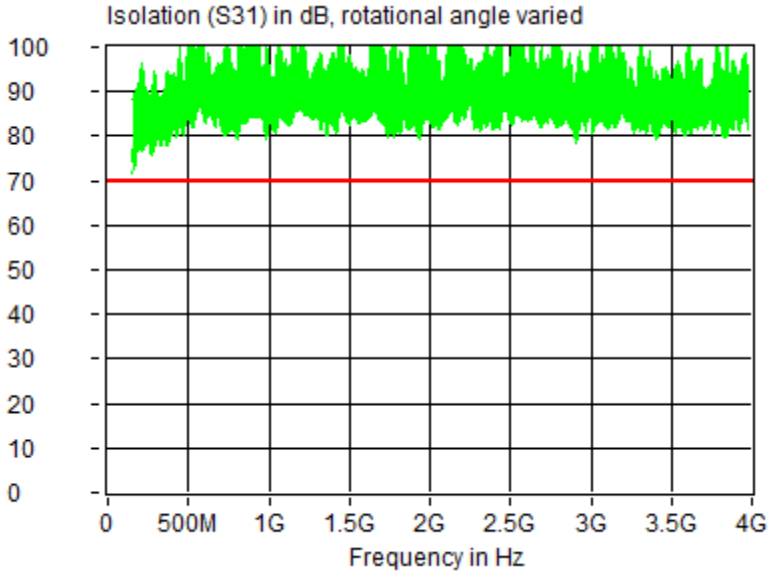


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<p>Absolute insertion loss difference</p>	<p>This parameter is only defined for two channels operating in the same frequency range. It describes the difference between their insertion loss figures at a certain frequency and rotational angle θ.</p> <p>"Absolute insertion loss difference, max." ILD_{max}, as given in SPINNER datasheets, describes the worst-case insertion loss difference value over the rotational angle θ within the operating frequency band:</p> $ILD(f, \theta) = a_{i,CH1}(f, \theta) - a_{i,CH2}(f, \theta)$ $ILD_{max} = \max_{f \in FR} \left\{ \max_{0^\circ \leq \theta < 360^\circ} ILD(f, \theta) \right\}$ <p>If required careful tuning of the internal cable lengths enables insertion loss matching of channels within 0.1 to 0.2 dB (for coaxial multichannel rotary joints).</p>												
<p>Absolute phase difference</p>	<p>Like insertion loss difference, this parameter is only defined for two channels operating in the same frequency range. It describes the difference between their insertion phases at a certain frequency and rotational angle θ.</p> <p>"Absolute phase difference, max." PD_{max}, as given in SPINNER datasheets, describes the worst-case phase difference value over the rotational angle θ within the operating frequency band:</p> $PD(f, \theta) = \varphi_{i,CH1}(f, \theta) - \varphi_{i,CH2}(f, \theta)$ $PD_{max} = \max_{f \in FR} \left\{ \max_{0^\circ \leq \theta < 360^\circ} PD(f, \theta) \right\}$ <p>If required careful tuning of the internal cable lengths enables phase matching of channels within a few degrees (for coaxial multichannel designs, depending on wavelength).</p> <p><u>Example:</u></p> <div data-bbox="523 1395 1305 1966" data-label="Figure"> <p style="text-align: center;">Phase difference (S21-S43) in degree, rotational angle varied</p>  <table border="1"> <caption>Approximate data points from the phase difference graph</caption> <thead> <tr> <th>Frequency (Hz)</th> <th>Phase Difference (Degrees)</th> </tr> </thead> <tbody> <tr> <td>1.01G</td> <td>34.0</td> </tr> <tr> <td>1.02G</td> <td>34.2</td> </tr> <tr> <td>1.04G</td> <td>34.8</td> </tr> <tr> <td>1.06G</td> <td>35.5</td> </tr> <tr> <td>1.08G</td> <td>36.5</td> </tr> </tbody> </table> </div>	Frequency (Hz)	Phase Difference (Degrees)	1.01G	34.0	1.02G	34.2	1.04G	34.8	1.06G	35.5	1.08G	36.5
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<p>Insertion loss tracking over rotation</p>	<p>Insertion loss tracking is only defined for two channels operating in the same frequency range. It describes their insertion loss synchronism over rotation.</p> <p>Two modules, each suffering from high insertion loss variation over rotation, can still result in a dual channel rotary joint with good insertion loss tracking since the two individual variations may be similar and therefore cancel out if combined properly.</p> <p>This parameter could also be expressed as "variation of insertion loss difference over rotation".</p> <p>"Insertion loss tracking, max." ILT_{max} is defined as the difference between the maximum and minimum insertion loss difference values over the rotational angle θ within the operating frequency band:</p> $ILT(f) = \max_{0^\circ \leq \theta < 360^\circ} \{ILD(f, \theta)\} - \min_{0^\circ \leq \theta < 360^\circ} \{ILD(f, \theta)\}$ $ILT_{max} = ILT(f_{ILT}) = \max_{f \in FR} \{ILT(f)\}$
<p>Phase tracking over rotation</p>	<p>Phase tracking is only defined for two channels operating in the same frequency range. It describes their phase synchronism over rotation.</p> <p>Two modules, each suffering from high phase variation over rotation, can still result in a dual channel rotary joint with good phase tracking since the two individual variations may be similar and therefore cancel out if combined properly.</p> <p>This parameter could also be expressed as "variation of phase difference over rotation".</p> <p>"Phase tracking, max." PT_{max} is defined as the difference between the maximum and minimum phase difference values over the rotational angle θ within the operating frequency band:</p> $PT(f) = \max_{0^\circ \leq \theta < 360^\circ} \{PD(f, \theta)\} - \min_{0^\circ \leq \theta < 360^\circ} \{PD(f, \theta)\}$ $PT_{max} = PT(f_{PT}) = \max_{f \in FR} \{PT(f)\}$ <p>Some applications, for example secondary surveillance radar (SSR), require well matched rotary joint channels (both insertion loss and phase) along with tracking requirements.</p>

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<p>Isolation</p>	<p>Describes the crosstalk between two channels.</p> <p>The amount of RF energy leaking from one channel to a second one is usually expressed as insertion loss (in dB) between one port of the first channel and another port of the second channel while all remaining ports are properly terminated. Depending on the choice of ports two different isolation types must be considered: Forward and reverse isolation. All isolation values given by SPINNER represent worst-case values including both forward and reverse isolation.</p> <p>Common values are some 50 to 70 dB while particular designs, especially waveguide rotary joints designed for exceptionally high power, allow for isolation values around 100 dB.</p> <p><u>Example:</u></p> 
<p>RF-shielding</p>	<p>RF shielding describes the amount of RF energy leaking from a channel out of the rotary joint into the surrounding space. It is often confirmed by analysis and expressed in dB.</p>
<p>DC carrying capability</p>	<p>Naturally, this parameter is only specified for contacting rotary joints. It describes the maximum DC current that can be safely transmitted over a rotary joint. This may be of relevance for applications where biased electronic assemblies are located close to the antenna. If high direct (or low frequency) current transfer is demanded, the RF power capability is usually compromised.</p> <p>Because of the delicate nature of several contact parts inside most RF rotary joints the DC carrying capability is commonly limited to currents of a few amperes and to low voltages.</p> <p>If higher DC or low frequency AC power transmission capabilities are desired, SPINNER encourages the use of slip ring assemblies particularly designed for this purpose.</p>
<p>Additive phase noise</p>	<p>Additive phase noise, also referred to as residual phase noise, is the self phase noise of a component that adds to an existing signal as it passes through it. In rotary joints additive phase noise is caused by small variations in insertion loss and electrical phase during operation.</p>

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4 Fiber Optic Characteristics

Interface type	Generally SPINNER FORJs come with fiber pigtails which are equipped with either standard telecom fiber optic connectors or customized connectors.
Fiber type	SPINNER FORJs are available with the following fiber types: 50/125 GI (gradient index, multimode) 62.5/125 GI (gradient index, multimode) 9/125 SM (step index, singlemode)
Wavelength	Portion of the electromagnetic spectrum which a component has been designed for and within which the respective specification is valid. SPINNER offers designs for the standard optical windows at 850 nm, 1310 nm or 1550 nm. FORJs for broadband applications are also available. In the following the wavelength range will be referred to as <i>WR</i> .
Average power capability	Maximum permissible long term ("continuous wave" or CW) power which a component can handle safely without internal overheating. Common values are 200 mW (23 dBm) for FORJs.
Return loss	Describes the logarithmic ratio (in dB) between incident power P_{in} and reflected power P_r at a component's port: $a_r = 10 \text{ dB} \cdot \lg \frac{P_{in}}{P_r}$ The return loss of a FORJ is determined in accordance to IEC 61300-3-6:2008 method 1. Any "return loss, min." figures given in SPINNER data sheets are worst-case values (usually between 40 dB and 55 dB for FORJs).
Insertion loss	Attenuation of a signal being passed through a device within the signal path. Insertion loss a_i is usually expressed as the logarithmic ratio (in dB) between incident power P_{in} and output power P_{out} . $a_i = 10 \text{ dB} \cdot \lg \frac{P_{in}}{P_{out}}$ The insertion loss of a FORJ is determined in accordance to IEC 61300-3-4:2012 insertion method (C). Insertion loss is somewhat temperature-dependent. SPINNER would like to point out that any insertion loss figures stated in SPINNER data sheets hold true for the entire specified range of operating temperatures and the nominal operating power. Any "insertion loss, max." figures given in SPINNER data sheets are worst-case values (usually between 1 dB and 4 dB for FORJs).

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<p>Insertion loss variation over rotation</p>	<p>Sometimes also named "insertion loss WOW", this parameter describes how much insertion loss changes over a full rotation at defined wavelengths.</p> <p>"Insertion loss variation over rotation, max." $\Delta a_{i,max}$ is defined as difference between the maximum and minimum insertion loss values measured at the wavelength which features the highest insertion loss variation over the rotational angle θ:</p> $\Delta a_i(\lambda) = \max_{0^\circ \leq \theta < 360^\circ} \{a_i(\lambda, \theta)\} - \min_{0^\circ \leq \theta < 360^\circ} \{a_i(\lambda, \theta)\}$ $\Delta a_{i,max} = \max_{\lambda \in WR} \{\Delta a_i(\lambda)\}$ <p>Any "insertion loss variation over rotation, max." values given in SPINNER data sheets are worst-case values (usually between 0.5 dB and 1.5 dB for FORJs).</p>
<p>Isolation</p>	<p>Describes the crosstalk between two channels.</p> <p>Any isolation values given by SPINNER represent worst-case values including both forward and reverse isolation. Common values are some 50 dB for FORJs.</p>

5 Mechanical Characteristics

<p>Differential operating pressure</p>	<p>Differential pressure between pressurized area within the RF part and environment indicated in MPa (10^6 Pa) and in bar.</p> <p>"Differential operating pressure, max.", as given in SPINNER datasheets, is valid for the complete operating ambient temperature range. The term "Differential operating pressure, nominal" describes the recommended operating condition.</p>
<p>Absolute operating pressure</p>	<p>Absolute pressure within the RF part of the rotary joint indicated in MPa and in bar.</p> <p>"Absolute operating pressure, min.", as given in SPINNER datasheets, describes the minimum pressure to be maintained in all operating conditions to ensure the peak power capability of the rotary joint. Depending on the type of insulating gas different minimum pressures need to be maintained.</p>
<p>Leakage rate</p>	<p>Leakage rate for pressurized wave guides valid for the indicated operating ambient temperature range. Usually indicated as maximum value valid at the indicated nominal differential pressure</p>
<p>Rotating speed</p>	<p>Rotational speed in rpm, Usually indicated as nominal and maximum speed.</p>
<p>Life</p>	<p>Life time usually indicated in number of revolutions. Life time is limited by the type (contacting) of transmission as well as by bearings and dynamic seals. The life time can be extended by dedicated maintenance tasks, available for some products.</p>
<p>Torque</p>	<p>The torque of a rotary joint gives the mechanical resistance during start up or turning at nominal speed. Usually these two values are indicated in Nm, for room temperature and for the minimum specified operating ambient temperature.</p> <p>If no temperature is indicated, the torque is defined at room temperature. Torque values for all other temperatures can be given upon request.</p>
<p>Interface loads</p>	<p>The interface loads coming from the installation of the rotary joint will have an effect on the bearing design. SPINNER rotary joints usually are not designed to withstand external forces; which means that no or no significant loads are</p>

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	allowed. In some case also some loads are indicated which can be introduced into the system. In that cases the loads are expressed as forces in axial and radial direction as well as the bending moment on the interface axis.
Case material	The case material is the material of the housings and main flanges. For the internal design also other materials are used. Typical materials are aluminum alloy, copper alloy or stainless steel.
Case surface finish	The case surface finish is the surface treatment of the housings and main flanges. For the internal design also other surface treatments are used. Some joints do not have any surface treatments, other typical treatments are chromate conversion coat per MIL-DTL-5541 (e.g. Surtech 650), silver plated or painted (e.g. two-component paints, PU-based, color according to RAL or other specifications).
Weight	Weight of rotary joint assembly without mounting screws and protective packing.
Marking	Marking or labeling of the rotary joint. Typical solutions are adhesive label, riveted label, laser engraving, engraving or stamping.

6 Environmental Conditions

Application	The application indicates the general environment of the installed rotary joint. The application is typically defined as airborne plane, airborne helicopter, ground fixed, ground mobile, shipboard, submarine, or satellite according to MIL-HDBK-217.
Ambient temperature range	Temperature range of the environment in °C. Typically indicated for operating and for storage condition. If not otherwise indicated SPINNER assumes that no heat from external sources is introduced into the rotary joint.
Relative humidity	The ratio of the actual vapor pressure of the air to the saturation vapor pressure in %. Typically indicated as a maximum value, valid for the complete temperature range (ambient or storage) It must be ensured, that condensation does not appear.
IP protection level	All IP protection levels are given according to EN 60529. Typical IP classes are: IP 40: Protection against wires and screws; no protection against liquids IP 54: Protection against dust & splashing water IP 65: Dust tight & protected against water jets The given IP classes are valid for all installation directions unless otherwise noted. To achieve the given IP class the rotary joint must be installed and connected correctly as well as mounted with the appropriate gaskets.
Shock	Information for the compliance demonstration according to MIL-STD-810G, Method 516 "Shock".
Vibration	Information for the compliance demonstration according to MIL-STD-810G, Method 514 "Vibration".
Salt fog	Information for the compliance demonstration according to MIL-STD-810G, Method 509 "Salt Fog".
Icing/Freezing Rain	Information for the compliance demonstration according to MIL-STD-810G, Method 521 "Icing/Freezing Rain".

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Fungus	Information for the compliance demonstration according to MIL-STD-810G, Method 508 "Fungus".
Rain	Information for the compliance demonstration according to MIL-STD-810G, Method 506 "Rain".
Sand and Dust	Information for the compliance demonstration according to MIL-STD-810G, Method 510 "Dust".
Room temperature	Room temperature is defined to $(20 \pm 5)^{\circ}\text{C}$