COAXIAL CONNECTORS

Japan Aviation Electronics Industry, Ltd.
Appendices

1. Unit conversion (122 to 123 Page)
   ① VSWR conversion
   ② dBm-W conversion

2. Glossary (124 to 126 Page)

3. Frequency designations (127 Page)

4. Calculation of the VSWR of connectors in cascade connection (128 to 130 Page)
## VSWR Conversion

### VSWR Conversion Chart

<table>
<thead>
<tr>
<th>VSWR</th>
<th>Reflection Coefficient</th>
<th>Return Loss (%)</th>
<th>Transmission Power (%)</th>
<th>Transmission Loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>( \frac{S-1}{S+1} )</td>
<td>(-10 \log \left( \frac{S-1}{S+1} \right)^2 \times 100)</td>
<td>(1 - \left( \frac{S-1}{S+1} \right)^2 \times 100)</td>
<td>(-10 \log \left( 1 - \left( \frac{S-1}{S+1} \right)^2 \right))</td>
</tr>
</tbody>
</table>

\[ \Gamma = \frac{1 + |\Gamma|}{1 - |\Gamma|} \]

\( \Gamma' \times 100 \)

\(-10 \log \left( \Gamma' \right) \times 100\)

\(1 - \Gamma' \times 100\)

\(-10 \log \left( 1 - \Gamma' \right)\)

<table>
<thead>
<tr>
<th>Reflection Coefficient ( \Gamma )</th>
<th>Reflection Coefficient ( \Gamma' )</th>
<th>Return Loss (( L_R ))</th>
<th>Transmission Power (( P_T ))</th>
<th>Transmission Loss (( L_T ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Gamma' ) \times 100 )</td>
<td>( \Gamma' \times 100 ) ( P_T ) (100 - P_T )</td>
<td>(-10 \log \left( \frac{\Gamma'}{10} \right) )</td>
<td>(-10 \log \left( \frac{\Gamma'}{10} \right) )</td>
<td>(-10 \log \left( \frac{\Gamma'}{10} \right) )</td>
</tr>
</tbody>
</table>

### VSWR Nomograph

![VSWR Nomograph](image-url)

<table>
<thead>
<tr>
<th>VSWR</th>
<th>Reflection Coefficient (%)</th>
<th>Return Loss (dB)</th>
<th>Transmission Power (%)</th>
<th>Transmission Loss (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>0.00</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1.04</td>
<td>0.01</td>
<td>99.9</td>
<td>0.02</td>
<td>1.15</td>
</tr>
</tbody>
</table>
### dBm-W Conversion

\[ A \text{ [dBm]} = 10 \log_{10} (B \text{ [mW]}) \]

<table>
<thead>
<tr>
<th>dBm</th>
<th>mW</th>
<th>dBm</th>
<th>mW</th>
<th>dBm</th>
<th>mW</th>
<th>dBm</th>
<th>mW</th>
<th>dBm</th>
<th>W</th>
<th>dBm</th>
<th>W</th>
<th>dBm</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10.0</td>
<td>0.100</td>
<td>0.0</td>
<td>1.00</td>
<td>10.0</td>
<td>10.0</td>
<td>20.0</td>
<td>100</td>
<td>30.0</td>
<td>1.00</td>
<td>40.0</td>
<td>10.0</td>
<td>50.0</td>
<td>100</td>
</tr>
<tr>
<td>-9.0</td>
<td>0.126</td>
<td>1.0</td>
<td>1.26</td>
<td>11.0</td>
<td>12.6</td>
<td>21.0</td>
<td>126</td>
<td>31.0</td>
<td>1.26</td>
<td>41.0</td>
<td>12.6</td>
<td>51.0</td>
<td>126</td>
</tr>
<tr>
<td>-8.0</td>
<td>0.158</td>
<td>2.0</td>
<td>1.58</td>
<td>12.0</td>
<td>15.8</td>
<td>22.0</td>
<td>158</td>
<td>32.0</td>
<td>1.58</td>
<td>42.0</td>
<td>15.8</td>
<td>52.0</td>
<td>158</td>
</tr>
<tr>
<td>-7.0</td>
<td>0.200</td>
<td>3.0</td>
<td>2.00</td>
<td>13.0</td>
<td>20.0</td>
<td>23.0</td>
<td>200</td>
<td>33.0</td>
<td>2.00</td>
<td>43.0</td>
<td>20.0</td>
<td>53.0</td>
<td>200</td>
</tr>
<tr>
<td>-6.0</td>
<td>0.251</td>
<td>4.0</td>
<td>2.51</td>
<td>14.0</td>
<td>25.1</td>
<td>24.0</td>
<td>251</td>
<td>34.0</td>
<td>2.51</td>
<td>44.0</td>
<td>25.1</td>
<td>54.0</td>
<td>251</td>
</tr>
<tr>
<td>-5.0</td>
<td>0.316</td>
<td>5.0</td>
<td>3.16</td>
<td>15.0</td>
<td>31.6</td>
<td>25.0</td>
<td>316</td>
<td>35.0</td>
<td>3.16</td>
<td>45.0</td>
<td>31.6</td>
<td>55.0</td>
<td>316</td>
</tr>
<tr>
<td>-4.0</td>
<td>0.398</td>
<td>6.0</td>
<td>3.98</td>
<td>16.0</td>
<td>39.8</td>
<td>26.0</td>
<td>398</td>
<td>36.0</td>
<td>3.98</td>
<td>46.0</td>
<td>39.8</td>
<td>56.0</td>
<td>398</td>
</tr>
<tr>
<td>-3.0</td>
<td>0.501</td>
<td>7.0</td>
<td>5.01</td>
<td>17.0</td>
<td>50.1</td>
<td>27.0</td>
<td>501</td>
<td>37.0</td>
<td>5.01</td>
<td>47.0</td>
<td>51.1</td>
<td>57.0</td>
<td>501</td>
</tr>
<tr>
<td>-2.0</td>
<td>0.631</td>
<td>8.0</td>
<td>6.31</td>
<td>18.0</td>
<td>63.1</td>
<td>28.0</td>
<td>631</td>
<td>38.0</td>
<td>6.31</td>
<td>48.0</td>
<td>63.1</td>
<td>58.0</td>
<td>631</td>
</tr>
<tr>
<td>-1.0</td>
<td>0.794</td>
<td>9.0</td>
<td>7.94</td>
<td>19.0</td>
<td>79.4</td>
<td>29.0</td>
<td>794</td>
<td>39.0</td>
<td>7.94</td>
<td>49.0</td>
<td>79.4</td>
<td>59.0</td>
<td>794</td>
</tr>
</tbody>
</table>
The transmission performance of a connector (insertion loss, return loss, isolation), for example, is expressed in decibels, in terms of a logarithm of the ratio between magnitudes of voltage, current and power.

Letting two different powers be \( P_1 \) and \( P_2 \):

\[
A[\text{dB}] = 10 \log \left( \frac{P_1}{P_2} \right) = 10 \log \left( \frac{1}{10^\frac{A}{10}} \right)
\]

With the voltage (with the current, \( I_1 \) and \( I_2 \), instead of \( V_1 \) and \( V_2 \)):

\[
B[\text{dB}] = 20 \log \left( \frac{V_1}{V_2} \right) = 20 \log \left( \frac{1}{10^\frac{B}{20}} \right)
\]

**[Characteristic Impedance]**

Ratio of voltage to the flow of current allowed in an alternating current transmission line. Impedance expressed in ohms is analogous to R in the equation of \( V=IR \) for a direct current circuit. With high frequencies, 50 ohms and 75 ohms are typical characteristic impedance values.

A good transmission characteristic is achieved by adjusting the input/output impedances of the device to 50 or 75 ohms. Also in the circuits inside the device, it is desirable to match the characteristic impedances in the whole region.

The characteristic impedance in the coaxial line is given by

\[
Z_c = \frac{60}{\sqrt{\varepsilon_r}} \ln \left( \frac{D}{d} \right)
\]

where \( \varepsilon_r \) = dielectric constant of the insulator

- \( d \) = outer diameter of the core conductor
- \( D \) = inner diameter of the outer conductor

**[Reflection Coefficient]**

Ratio between the reflected voltage wave \( V_2 \) and the incident voltage wave \( V_1 \).

\[
\Gamma = \frac{V_2}{V_1}
\]

The value \( |\Gamma| \leq 1 \). With a higher degree of impedance matching, producing less reflection, the coefficient approaches zero.

If a load impedance \( Z_L \) is connected to a transmission line with a characteristic impedance \( Z_c \), reflection occurs.

The equation for the reflection coefficient at the connection point can be written as

\[
\Gamma = \frac{Z_L - Z_c}{Z_L + Z_c}
\]
[Return Loss]
Logarithmic expression of the ratio between reflecting power \( P_r \) and incident power \( P_i \) to the circuit/connector.

\[
RL = -10 \log \left( \frac{P_r}{P_i} \right) \text{ [dB]}
\]

This can be rewritten in terms of the reflection coefficient \( \Gamma \).

\[
RL = -10 \log |\Gamma| \text{ [dB]}
\]

[V.S.W.R. (voltage standing wave ratio)]
A standing wave may be formed by interference between a wave transmitted into a transmission line and a reflected wave. V.S.W.R. is the ratio of the absolute value of maximum voltage and that of minimum voltage in the standing wave pattern. With a higher degree of impedance matching, the value of V.S.W.R. approaches 1.

\[
VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}
\]

Either return loss or V.S.W.R. is selected as a product specification.

[Insertion Loss]
Logarithmic expression of the ratio of output power \( P_o \) to input power \( P_i \) of the circuit/connector. It is sometimes simply referred to as "attenuation" or "loss."

\[
IL = -10 \log \left( \frac{P_o}{P_i} \right) \text{ [dB]}
\]

\[
\frac{P_o}{P_i} = 10^{-\frac{IL}{10}}
\]

[S Parameter (Scattering Parameter)]
With high frequencies, it is difficult to directly measure the voltage and current in a transmission line. The circuit characteristic can be expressed by the power measured instead of voltage or current. The S parameter is an expression that is dependent on the amplitude and phase at each port (observation point). V.S.W.R. and insertion loss described above can be obtained from the S parameter.

\[
\begin{align*}
S_{11} & = P_{11} / P_{in} \\
S_{21} & = P_{21} / P_{in} \\
S_{12} & = P_{12} / P_{in} \\
S_{22} & = P_{22} / P_{in}
\end{align*}
\]

An example of S parameter with two ports

[Wave Length]
Distance the electric wave travels per cycle (1Hz). In a dielectric substance such as plastic insulator, the wavelength is reduced by its relative magnetic permeability.

\[
\lambda = \frac{c}{f \varepsilon_r}
\]

where \( c \) = velocity of light \( f \) = frequency \( \varepsilon_r \) = relative permittivity of the insulator

The higher the frequency, the shorter the wavelength. As the wavelength approaches the circuit dimension, the wavelength increases in importance as a distribution constant.
[Skin Effect]
Direct current is uniformly distributed in the conductor section. High-frequency currents, however, flow in a narrow skin of the conductor - hence the name “skin effect.” The distance below the conductor surface where the intensity of the magnetic field falls to 1/e or about 37% of its value at the conductor surface, is defined as skin depth, and is given by
\[
\delta = \frac{\rho}{\pi f \mu_0 \mu_r}
\]
where \( \rho \) = resistivity of the conductor \( f \) = frequency
\( \mu_0 \) = magnetic permeability of vacuum \( \mu_r \) = relative magnetic permeability of the conductor

Since signals exceeding the GHz band flows in a very narrow skin of several micrometers, the conductor loss increases.

[TEM Mode (Transverse Electromagnetic Mode)]
Dominant mode of electromagnetic wave transmitted in a coaxial line. Electric field in a section in a coaxial line is distributed radially from the core conductor to the outer conductor, whereas magnetic field forms concentric circles. The direction of the electric and magnetic fields is orthogonal, i.e., transverse, to the direction the wave is moving. Hence the abbreviated name, TEM.

[Cutoff Frequency]
In the electromagnetic field distribution in a coaxial line, a higher mode may occur depending upon the relationship between wavelength and line diameter, resulting in poorer propagation characteristics. The frequency at which the higher mode theoretically occurs is called the cutoff frequency, which is given by
\[
\nu_c = \frac{2c}{\pi (d + D) \sqrt{\varepsilon_r}}
\]
where \( c \) = velocity of light \( d \) = outer diameter of the core conductor
\( D \) = inner diameter of the outer conductor \( \varepsilon_r \) = relative permittivity of the insulator

The frequency in the coaxial line should be lower than the cutoff frequency.

[dBm]
A measure of absolute power value in decibels. Zero dBm equals to one milli watt.

[Hz]
Number of signal cycles repeating per second.

[bps (bits per second)]
Number of bits transmitted per second.
## Frequency designations

<table>
<thead>
<tr>
<th>Frequency designations</th>
<th>Wave Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>LF (Low frequency)</td>
<td>30kHz</td>
</tr>
<tr>
<td>MF (Medium frequency)</td>
<td>300kHz</td>
</tr>
<tr>
<td>HF (High frequency)</td>
<td>3MHz</td>
</tr>
<tr>
<td>VHF (Very high frequency)</td>
<td>30MHz</td>
</tr>
<tr>
<td>UHF (Ultra high frequency)</td>
<td>300MHz</td>
</tr>
<tr>
<td>SHF (Super high frequency)</td>
<td>3GHz</td>
</tr>
<tr>
<td>EHF (Extremely high frequency)</td>
<td>300GHz</td>
</tr>
</tbody>
</table>
You cannot obtain the VSWR of the circuits of connectors, cables or components in cascade connection (mating), even when the VSWR of each circuit is known, unless the S-parameter of each circuit is obtainable. The VSWR shall be calculated at each frequency.

**Calculation of VSWR**

You can calculate VSWR by using $S_\alpha$ of S-parameters

\[(a + jb) \text{ or } (r \angle \theta)\]

From \[r \angle \theta = r(\cos \theta + j \sin \theta)\]

\[|T|^2 = |S_\alpha|^2 = |a^2 + b^2| \quad \text{VSWR} = \frac{1 + |r|}{1 - |r|}\]

**S-parameters of connectors in cascade connection**

![Diagram of S-parameters of connectors in cascade connection]

Transform the S-parameter of each connector into a T-parameter.

\[
\begin{bmatrix}
T_{11} & T_{12} \\
T_{21} & T_{22}
\end{bmatrix} = \begin{bmatrix} 1 & -S_\alpha S_\beta + S_\theta S_\beta \\ -S_\theta & 1 \end{bmatrix} \quad (i = 1, 2, \ldots, n)
\]

Calculate the product of the matrices of T-parameters,

\[
\begin{bmatrix}
T(1)_{11} & T(1)_{12} & T(1)_{21} & T(1)_{22} \\
T(2)_{11} & T(2)_{12} & T(2)_{21} & T(2)_{22} \\
\vdots & \vdots & \vdots & \vdots \\
T(n)_{11} & T(n)_{12} & T(n)_{21} & T(n)_{22}
\end{bmatrix}
\]

Inversely transform T-parameters into S-parameters.

\[
\begin{bmatrix}
S_{11} & S_{12} \\
S_{21} & S_{22}
\end{bmatrix} = \begin{bmatrix} 1 & T_{11} T_{21} - T_{12} T_{22} \\ T_{21} & T_{22} \end{bmatrix} \quad (i = 1, 2, \ldots, n)
\]

The S-parameter thus obtained gives the S-parameter of the coaxial connectors in cascade connection.

By this method, you can calculate the S-parameter of the entire circuit (including VSWR) based on the S-parameter of each connector in cascade connection.
Calculation of the VSWR of connection in cascade connection

An example (connectors 1 and 2 in cascade connection)

Let's calculate VSWR at 2GHz here as an example.

The S-parameter of each connector at 2GHz is measured as:

\[
\begin{bmatrix}
S(1)_{11} & S(1)_{12} \\
S(1)_{21} & S(1)_{22}
\end{bmatrix} = \begin{bmatrix}
0.029988 - 0.002592j & 0.408634 - 0.90502j \\
0.409045 - 0.90595j & 0.023405 + 0.01555j
\end{bmatrix}
\]

\[
\begin{bmatrix}
S(2)_{11} & S(2)_{12} \\
S(2)_{21} & S(2)_{22}
\end{bmatrix} = \begin{bmatrix}
-0.007512 - 0.01413j & 0.642835 - 0.76339j \\
0.642835 - 0.76339j & -0.01136 - 0.007661j
\end{bmatrix}
\]

The above S-parameters can be transformed into the following T-parameters

\[
\begin{bmatrix}
T(1)_{11} & T(1)_{12} \\
T(1)_{21} & T(1)_{22}
\end{bmatrix} = \begin{bmatrix}
0.968064 - 68.226j & 0.07518 - 0.0006793j \\
0.511292 - 0.008163j & 0.0002302 + 0.01522j
\end{bmatrix}
\]

\[
\begin{bmatrix}
T(2)_{11} & T(2)_{12} \\
T(2)_{21} & T(2)_{22}
\end{bmatrix} = \begin{bmatrix}
7.8211 + 295.214j & 2.36379 - 0.04696j \\
-2.9247 + 0.05822j & 0.0004006 + 0.02003j
\end{bmatrix}
\]

(1) VSWR viewed from the connector 1 when connectors 1 and 2 are connected in this order (connector 1 + connector 2)

Transform S-parameters into T-parameters and calculate the product of the matrices of T-parameters.

\[
\begin{bmatrix}
T(\text{All})_{11} & T(\text{All})_{12} \\
T(\text{All})_{21} & T(\text{All})_{22}
\end{bmatrix} = \begin{bmatrix}
T(1)_{11} & T(1)_{12} \\
T(1)_{21} & T(1)_{22}
\end{bmatrix} \begin{bmatrix}
T(2)_{11} & T(2)_{12} \\
T(2)_{21} & T(2)_{22}
\end{bmatrix} = \begin{bmatrix}
-0.42919 - 0.8943j & -0.02174 + 0.01689j \\
-0.03027 - 0.01444j & -0.43595 + 0.90886j
\end{bmatrix}
\]

Inversely transform T-parameters thus obtained into S-parameters.

\[
\begin{bmatrix}
S(\text{All})_{11} & S(\text{All})_{12} \\
S(\text{All})_{21} & S(\text{All})_{22}
\end{bmatrix} = \begin{bmatrix}
0.02444 + 0.01219j & -0.42862 - 0.89358j \\
-0.42905 - 0.89448j & -0.00007447 - 0.03327j
\end{bmatrix}
\]
Calculation of the VSWR of connection in cascade connection

When the connector 1 and connector 2 are connected in this order, the VSWR of this combination viewed from the connector 1 is calculated as 1.056 at 2GHz from $S_{\text{All}}(n)$, which is measured as 1.059.

(Reference)
VSWR at 2GHz (measured)
Connector 1 (unit): 1.062
Connector 2 (unit): 1.032

(2) VSWR of the combined connectors viewed from the connector 2 when connectors 2 and 1 are connected in this order (connector 2 + connector 1)

※ Pay attention to the directions of connectors ① and ②.

VSWR =

\[
\begin{bmatrix}
S(2)_{11} & S(2)_{12} \\
S(2)_{21} & S(2)_{22}
\end{bmatrix}
\] ① ②

Connector 2

\[
\begin{bmatrix}
S(1)_{11} & S(1)_{12} \\
S(1)_{21} & S(1)_{22}
\end{bmatrix}
\] ① ②

Connector 1

\[
\begin{bmatrix}
S_{\text{All}}(2)_{11} & S_{\text{All}}(2)_{12} \\
S_{\text{All}}(2)_{21} & S_{\text{All}}(2)_{22}
\end{bmatrix}
\] ① ②

Connector 2 + Connector 1

Similarly, calculate the product of the matrices of the transformed T-parameters.

\[
\begin{bmatrix}
T_{\text{All}}(1)_{11} & T_{\text{All}}(1)_{12} \\
T_{\text{All}}(1)_{21} & T_{\text{All}}(1)_{22}
\end{bmatrix}
= \begin{bmatrix}
T(2)_{11} & T(2)_{12} \\
T(2)_{21} & T(2)_{22}
\end{bmatrix}
\begin{bmatrix}
T(1)_{11} & T(1)_{12} \\
T(1)_{21} & T(1)_{22}
\end{bmatrix}
= \begin{bmatrix}
-0.42923 - 0.89477j & 0.0458 + 0.005022j \\
0.03729 - 0.01025j & -0.4359 + 0.90933j
\end{bmatrix}
\]

Inversely transform T-parameters thus obtained into S-parameters

\[
\begin{bmatrix}
S_{\text{All}}(2)_{11} & S_{\text{All}}(2)_{12} \\
S_{\text{All}}(2)_{21} & S_{\text{All}}(2)_{22}
\end{bmatrix}
= \begin{bmatrix}
-0.01514 - 0.04311j & -0.42823 - 0.89332j \\
-0.42866 - 0.89422j & 0.02514 + 0.02896j
\end{bmatrix}
\]

When the connector 2 and connector 1 are connected in this order, the VSWR of this combination viewed from the connector 2 is calculated as 1.096 at 2GHz from $S_{\text{All}}(n)$, which is measured as 1.091.

(Reference)
VSWR at 2GHz (measured)
Connector 1 (unit): 1.062
Connector 2 (unit): 1.032

\[
\begin{bmatrix}
S_{\text{All}}(1)_{11} & S_{\text{All}}(1)_{12} \\
S_{\text{All}}(1)_{21} & S_{\text{All}}(1)_{22}
\end{bmatrix}
= \begin{bmatrix}
-0.01514 - 0.04311j & -0.42823 - 0.89332j \\
-0.42866 - 0.89422j & 0.02514 + 0.02896j
\end{bmatrix}
\]

\[
\begin{bmatrix}
S(2)_{11} & S(2)_{12} \\
S(2)_{21} & S(2)_{22}
\end{bmatrix}
\] ① ②

Connector 2

\[
\begin{bmatrix}
S(1)_{11} & S(1)_{12} \\
S(1)_{21} & S(1)_{22}
\end{bmatrix}
\] ① ②

Connector 1

\[
\begin{bmatrix}
S_{\text{All}}(2)_{11} & S_{\text{All}}(2)_{12} \\
S_{\text{All}}(2)_{21} & S_{\text{All}}(2)_{22}
\end{bmatrix}
\] ① ②

Connector 2 + Connector 1
Before placing an order

① The values specified in this catalogue are only for reference. The products and specifications are subject to change without notice. Contact our sales staff for further information before considering or ordering any of our products. For purchase, a product specification must be agreed upon.
② Users are requested to provide protection circuits and redundancy circuits to ensure safety of the equipment, and sufficiently review the suitability of JAE’s products to the equipment.
③ The products presented in this catalogue are designed for the uses recommended below. We strongly suggest you contact our sales staff when considering use of any of the products in any other way than the recommended applications or for a specific use that requires an extremely high reliability.

(1) Applications that require consultation:
(i) Please contact us if you are considering use involving a quality assurance program that you specify or that is peculiar to the industry, such as:
   - Automotive electrical components, train control, telecommunications devices (mainline), traffic light control,
   - Electric power, combustion control, fire prevention or security systems, disaster prevention equipment, etc.
(ii) We may separately give you our support with a quality assurance program that you specify, when you think of a use such as:
   - Aviation or space equipment, submarine repeaters, nuclear power control systems,
   - Medical equipment for life support, etc.

(2) Recommended applications include:
   - Computers, office appliances, telecommunications devices (terminals, mobile units), measuring equipment,
   - Audiovisual equipment, home electric appliances, factory automation equipment, etc.