APPLICATION TIPS

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What is Impedance?

Impedance is the combined effect of electrical resistance and reactance. In a direct current circuit, the impeding effect on electric current is called resistance. In the field of alternating current, in addition to the resistance, capacitance and inductance also impede the flow of current; this effect is called reactance. Reactance has the effect of resisting time-varying electric current.

Why impedance matching is needed

Impedance matching simply means mutually adapting the load impedance and internal impedance of the excitation source. The goal of matching is to maximize output power. Antenna impedance matching means adapting the transmission line between the antenna (load) and the radio-frequency (RF) circuit. When there is impedance mismatch, part of RF power is bounced back, resulting in loss of power, whereas, when there is an exact match between transmission line impedance and antenna impedance, all the RF power is transmitted to the antenna.

A system's impedance values *(also referred to as characteristic impedance)* can differ from application to application. In the telecommunications industry, the most common impedance is 50 Ohms. Therefore, the impedance value for most antennas should be as close to 50 Ohms as possible.

The Smith chart

The Smith chart is designed to help electronic and communications engineers understand and match the impedance of a source or load along a transmission line.

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What is impedance?

The input impedance for a transmission line changes with its length, requiring complex calculations to design a matching circuit. The Smith chart simplifies the process using a quick graphical solution. The chart is based on equation **$\Gamma = (Z - 1) / (Z + 1)$**

In the equation, **Γ** represents the reflection coefficient of the circuit (S11 in S-parameter), Z represents normalized load value, namely Z_L/Z_0, in which Z_L is the load value for the circuit (or the antenna) and Z_0 is the characteristic impedance for the transmission line, normally 50 Ohms.

As shown in **Figure 1,** the horizontal axis of the chart represents the real part of reflectance, and the vertical axis represents the imaginary part. Green circular lines represent circles of equal resistance, the transverse line and the lines radiating up and down (black) represent circles of equal reactance. As reflectance is less than or equal to 1, the equal reactance circles falling outside the unit circle are meaningless. The middlemost point in the chart, namely load ($Z = 1 + j0$, $\Gamma = 0$), represents a matched resistance value (here $Z_L = Z_0$, namely Z=1), and the value of its reflectance is 0. At the edge of the chart amplitude of the reflectance is 1 i.e. 100% reflection, the right hand (1,0) represents the open dot and the left hand (-1,0) represents the short dot. Certain charts are labeled in terms of admittance instead of impedance, in that case, simply rotate the above versions of impedance value by 180 degrees.

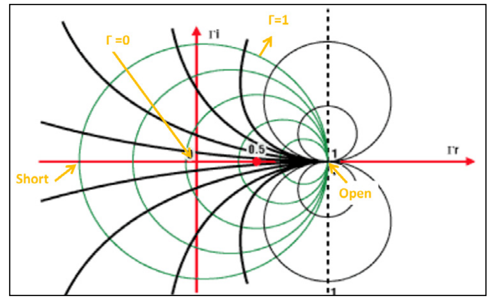

Figure 1

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What is impedance?

How to tune (i.e. match) antennas?

An antenna is treated as a load in the RF communication system, normally coming at the end of the RF circuit "design chain" or RF "front end". Instead of consuming all the energy in the form of heat or another mechanical process, the antenna radiates the signal into free space. To minimize the mismatch and losses, the impedance at the operating frequency of the antenna needs to be tuned to as close to 50 Ohms as possible.

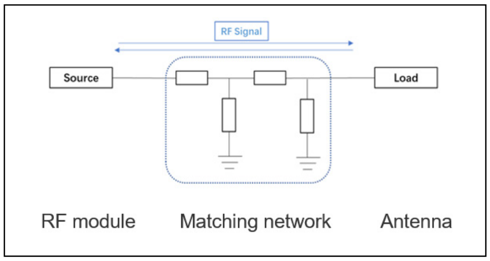

Figure 2

As shown in **Figure 2,** the RF module and antenna are typically connected by a matching circuit, which will be tuned to make the antenna and RF circuit work effectively together. The matching network circuit might be a capacitor, an inductor, a resistor or a length of the transmission line. The purpose of antenna matching tuning is to ensure the return loss of an antenna is minimized within the frequency band required by the antenna. In most cases, however, an antenna supports multiple bands, and a return loss of less than -6dB could be regarded as acceptable. The tuning procedures are described in detail below, but the general goal is to match/move the band of interest to the center of the Smith chart circle.

1. Calibrate the vector network analyzer, including all cabling.
2. Measure the antenna impedance with the network analyzer and match the impedance using the Smith chart.
3. Choose an appropriate capacitor and inductor, which will then be soldered to the solder pads for matching

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What is impedance?

networks on the printed circuit board. Impedance responses differ for capacitance and inductance by frequency, but as a rule-of-thumb, an impedance at a lower frequency is tuned using a shunt inductor and series capacitor, whereas an impedance at a higher frequency is tuned using a shunt capacitor and series inductor. **Figure 3** shows how to match capacitors and inductors.

4. Measure antenna impedance or the voltage standing wave ratio against the requirement.

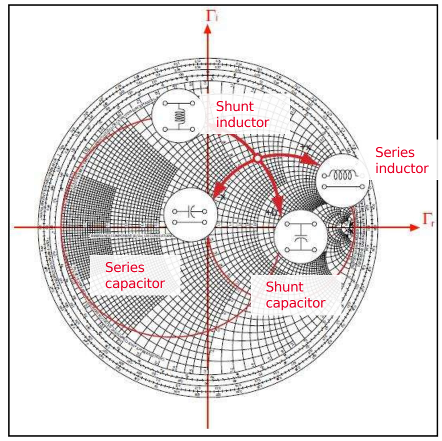

Figure 3

When selecting parts and components for matching, the following rules are often observed:

- The capacitance of the shunt capacitor should not be excessive, because the higher the capacitance, the lower the capacitive reactance, making it easier for the signal to flow to ground.
- The capacitance and inductance should not be too low. The lower the capacitance and inductance, the greater the impact of tolerances, which affect batch stability.
- The capacitance and inductance should be as conventional as possible, to make it easier to obtain replacement or spare parts.

Order No. 987652-2713 USA/0k/GF/2020.08