Bluetooth and Antenna Matching

Introduction

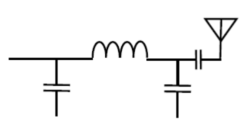
Antenna matching is an important aspect of any RF system. A properly designed and matched antenna increases the operating distance of the wireless product. Well matched antennas can transmit more power from the radio – therefore transmit over longer distances.
Likewise, a well matched antenna allows the maximum transfer of energy from the receiving antenna to the receiver front end. Thus, allowing better receive characteristics for the system.

Antenna matching becomes critical as antennas are reduced in size and placed in small modules that can experience wide temperature ranges and potentially have foreign objects in proximity.
This paper discusses one class of intermediate Q capacitors used for SMT antenna matching.

Background

Many applications are driven into small size modules for cost and ease of system integration. An example of this is automotive Bluetooth modules.
In this case, the use of SMT chip antennas offers a very good solution to designers.
SMT chip antennas take up minimal PCB area and offer reasonable performance across frequency. However, the use of chip antennas typically increases the BOM and assembly expense over PCB and wire antennas. Additionally, SMT antennas performance is very relative to the ground plane they are placed upon. Unlike PCB and wire antennas – they cannot be trimmed to accomplish tuning. Therefore, external components are required for tuning and impedance matching.

The goal of impedance matching is to match the module's output to the 50 ohm load of the antenna. Once this is accomplished most of the power from the RF source is delivered to the load in the transmit mode, and most energy is transferred from the antenna to the receiver front end in the receive mode. The exact circuit for matching an antenna and module will depend upon the antenna type, RF module used, ground plane, and system specifics etc. Regardless of the exact system details – inductors and capacitors will be used in a variety of configurations to accomplish the necessary impedance transformation to accomplish matching. An example of one type of matching network is shown below.



Some general suggestions for capacitor selection in the matching network are:

1. Using C0G (NPO) or higher Q capacitors reduce loss
2. Use tight tolerance capacitors
3. Consider the effects of case size on capacitor performance. Either use small case size capacitors – or define and take into account the expected parasitics of larger case size capacitors.
4. Be careful in pad layout – added parasitics will effect capacitor response and losses

5. Choose capacitors that have a self-resonant frequency equal to or better than 2x the frequency of operation
6. DC block capacitors should be added once the circuit is matched. The DC blocking capacitor should be chosen that the capacitor is operating at or slightly below its SRF. The capacitor has minimal ESR at this point and its effective reactive losses are minimized. Under this condition it does not alter the impedance matching.

Capacitor Selection and Simulation Data Available

One of the most widely used intermediate Q capacitors used in general purpose RF module matching is the U Dielectric series MLCC. The U dielectric series is a C0G (NP0) chip capacitor specially designed for ultra-low ESR for applications. Available EIA chip sizes are 0402, 0603, 0805 and 1210.

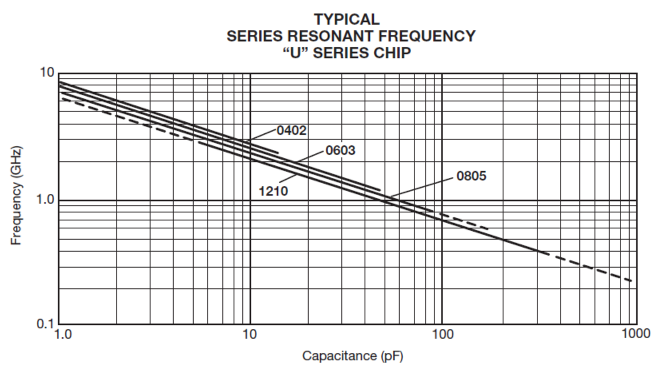
For additional information regarding AVX Automotive U Dielectric series MLCCs:
http://www.mouser.com/new/AVX/avx-rf-products/

A wide variety of capacitance values are offered from 0.2pF to 1nF, and tolerances down to 0.1pF are available on lower value capacitors.

These capacitors have exceptional loss performance relative to other C0G (NPO) types and have lot-to-lot stability beyond standard NPO devices. Each individual U dielectric lot must meet a specified maximum ESR and effective capacitance requirement by capacitance value and case size.

Further, U series have detailed performance data available such as resonant frequency data.

The resonant frequency by capacitance value is shown in the figure below in order to aid selection of filter capacitors and DC blocking capacitors (rules 5 & 6 above).



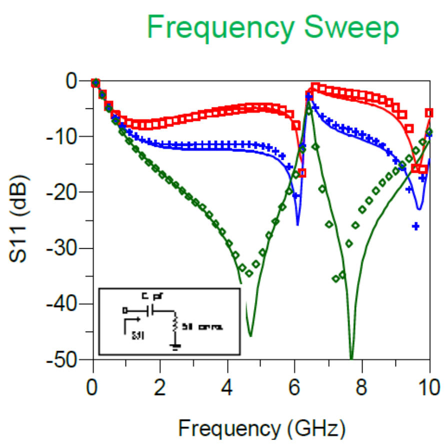
Additionally, and of great benefit to designers, RF models for U dielectric capacitors are available at Modelithics.

Downloads of device simulations are available at:

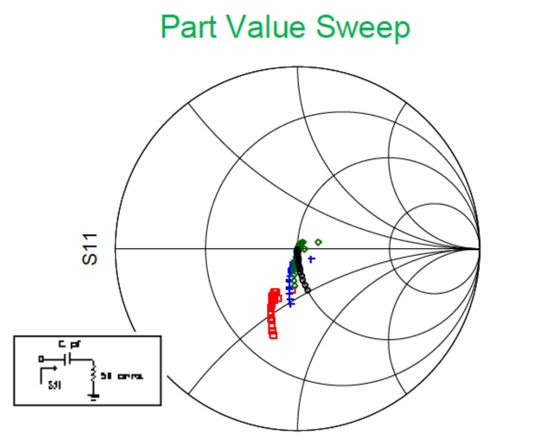
https://www.modelithics.com/mvp/avx

These models support popular simulation software tools such as Keysight Advanced Design System, National Instruments AWR Design Environment, Keysight Genesys, and ANSYS Electronics Desktop HFSS. The models are scalable by value, pad dimensions, and substrate. Further, orientation (electrodes vertical or horizontal on the PCB) selectability is available. The above software simulation features provide designers the information to satisfy answers for design rules 2, 3 and 4 (above).

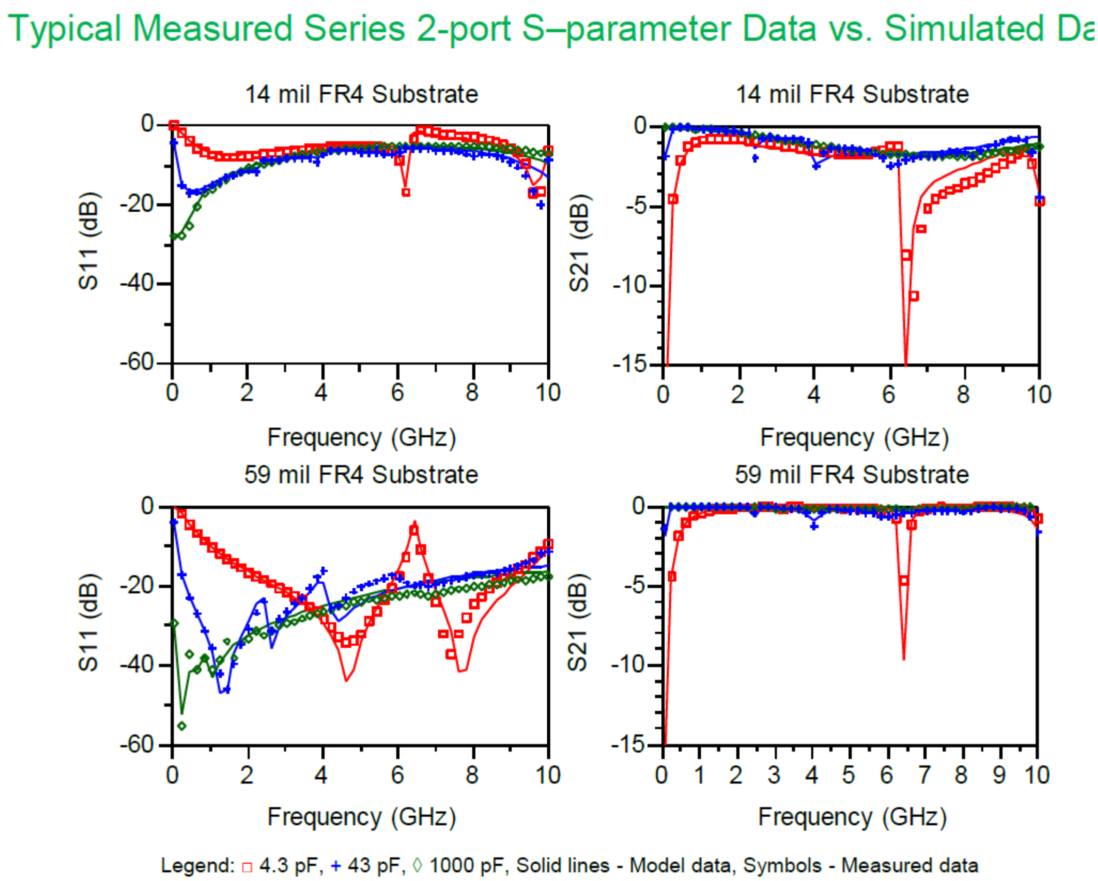
As an example, excerpts of U dielectric part performance available from Modelithic models follows:



Legend: □ 14mil FR4, + 31mil FR4, ◊ 59mil FR4, Lines - Model, Symbols - Measured data. Measured data stops at highest valid frequency for each substrate.
S11 for 4.3 pF capacitor mounted on various substrates from 0.04 to 10 GHz.



Legend: □ 14mil FR4, + 31mil FR4, ◊ 59mil FR4, O Ideal
Model S11 at 2 GHz for capacitor values from 3.3 to 1000 pF on various substrates compared to an ideal capacitor response.



Summary

The U dielectric series MLCC is a low-loss intermediate Q RF capacitor capable of high performance in antenna matching applications.

Consistent lot-to-lot performance is built into this device. Detailed RF characterization and simulation makes the use of these capacitors easy and risk free.