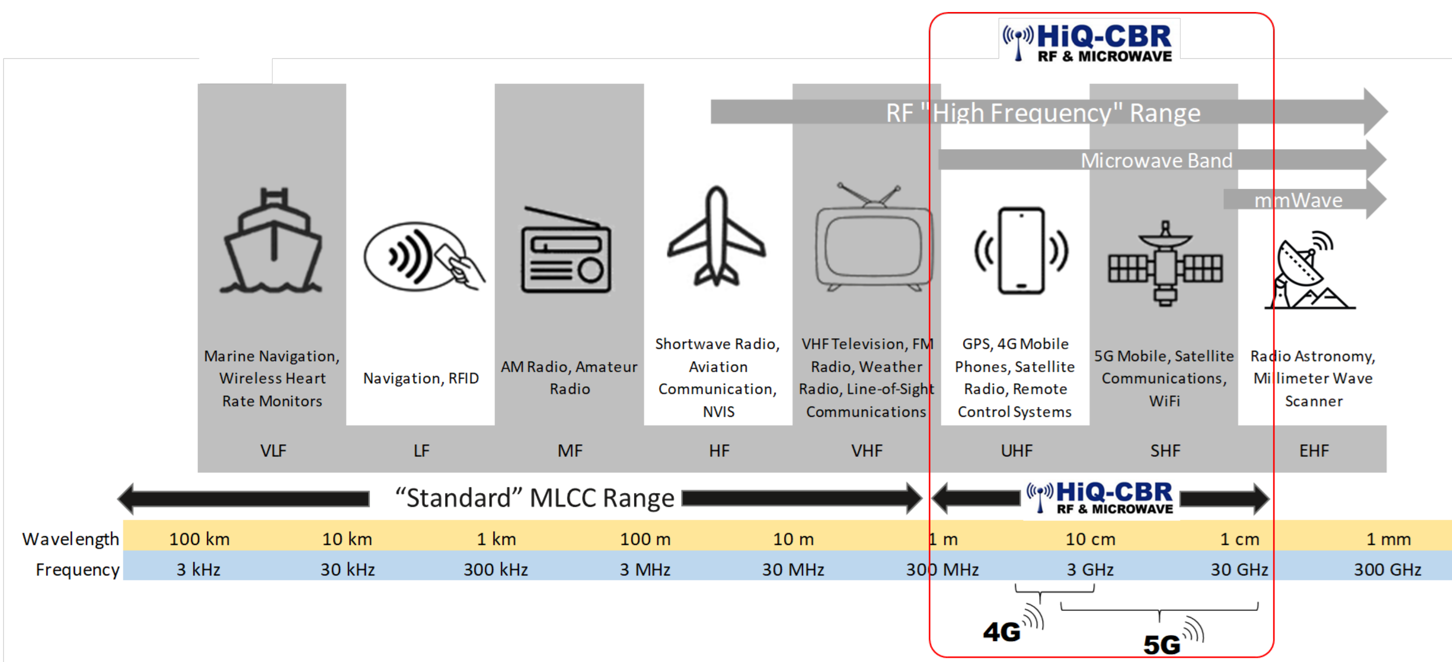
FAQs

HiQ High Frequency RF Capacitors (CBR Series)

What does RF Stand For?

RF stands for Radio Frequency, which has a frequency range of 30kHz – 300GHz. However, when referring to RF capacitors, the frequency range is usually 300MHz – 50GHz. Below 300MHz, standard MLCCs are suitable.



What is an RF Capacitor?

An RF capacitor is a capacitor whose "characteristics" are optimal at RF frequencies.

Key Characteristic	RF Capacitor Requirements
ESR (Equivalent Series Resistance)	Lowest possible ESR at RF frequencies
Q (Quality Factor)	High Q at RF frequencies
SRF (Series Resonant Frequencies)	High SRF as high as possible
TCC (Temperature Coefficient of Capacitance)	Minimal capacitance shift across temperature

Therefore, for RF capacitors, materials are chosen, and designs are optimized so that the capacitor's characteristics are optimal at the higher frequencies.

What are typical applications for RF capacitors?

RF MLCCs are used for bypass, coupling, filtering, impedance matching and DC blocking purposes.
Typical applications include:

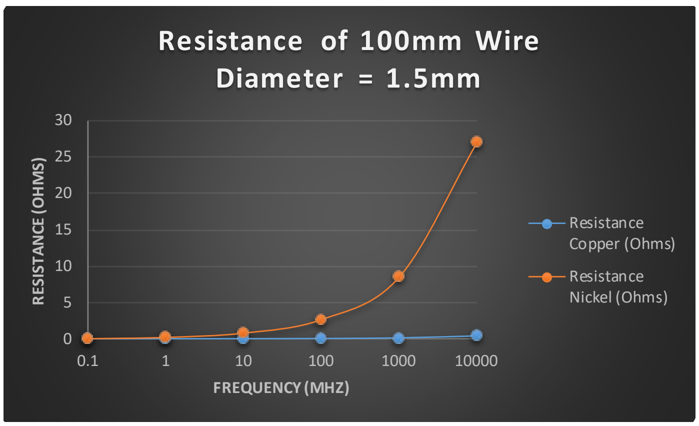
- RF power amplifiers (PA)
- Cellular base stations (4G, 5G)
- Wireless LAN
- Telecommunication Networks
- GPS
- Bluetooth
- Radar
- Automotive V2X, Safety Systems, Power Train, Communication Systems

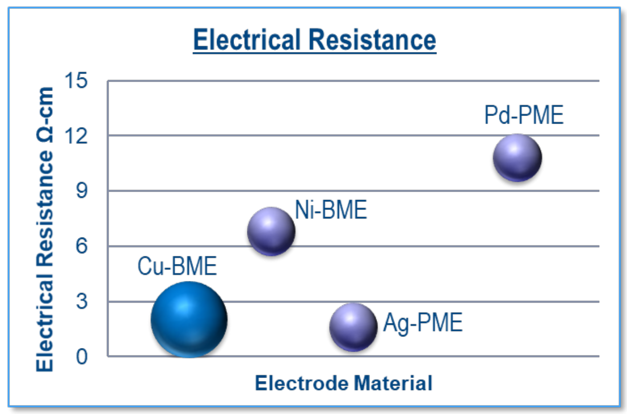
What is the difference between standard Ceramic Capacitors and HiQ RF capacitors?

Roughly 99% of all ceramic capacitors shipped every year are Base Metal Electrode systems where the inner electrodes are made of nickel. Since RF capacitors require very low loss at high frequencies, the internal electrodes are either Palladium Silver for Precious Metal Electrode (PME) systems or Copper for Base Metal Electrode (BME) systems.

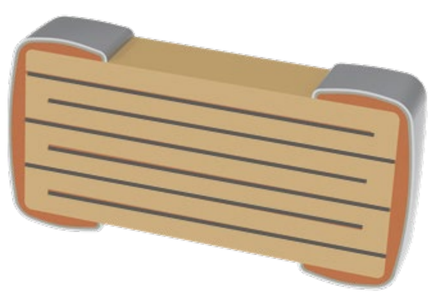
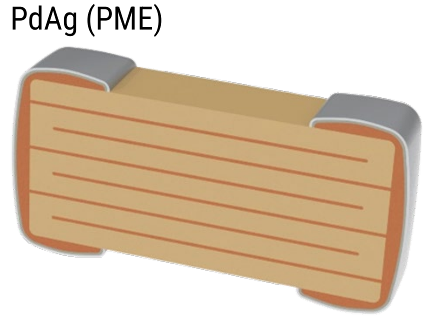
Since nickel is a ferrous material, its resistance increases dramatically at higher frequencies compared to copper. The bottom left plot below shows resistance of a 1.5mm diameter wire made from copper and nickel versus frequency. The plot shows that the nickel wire's resistance starts increasing above 10MHz while the copper wire's resistance increase is negligible in the GHz frequency range. Therefore, nickel electrodes are not preferred for RF capacitors.

In some RF capacitors, PdAg may be used which does provide good ESR at higher frequencies. However, with the increasing costs of precious metals, copper-based RF capacitors provide a great balance of excellent RF performance at a competitive cost.





KEMET's CBR series utilizes copper electrodes to maintain very low losses at high frequencies.

Characteristic	**Standard Ceramic Capacitor**	**HiQ RF Ceramic Capacitor**
Frequency Range	Low Frequencies <100MHz	Higher frequencies >100MHz
Electrode System	Nickel (BME) 	Copper (BME) PdAg (PME) 
ESR	Low ESR	Very Low ESR
Q-Factor	Moderate Q-Factor	High Q-Factor
Class I or Class II	Class I or Class II Dielectrics	Class I

What makes KEMET's CBR Automotive Grade RF capacitors automotive grade?

KEMET's CBR Automotive Grade RF capacitors utilize the same dielectric and electrode materials as the standard CBR series. However, the automotive grade CBR series is qualified, manufactured and tested per the stringent AEC-Q200 automotive standard.

What is Q or Quality Factor and how does it relate to Dissipation Factor?

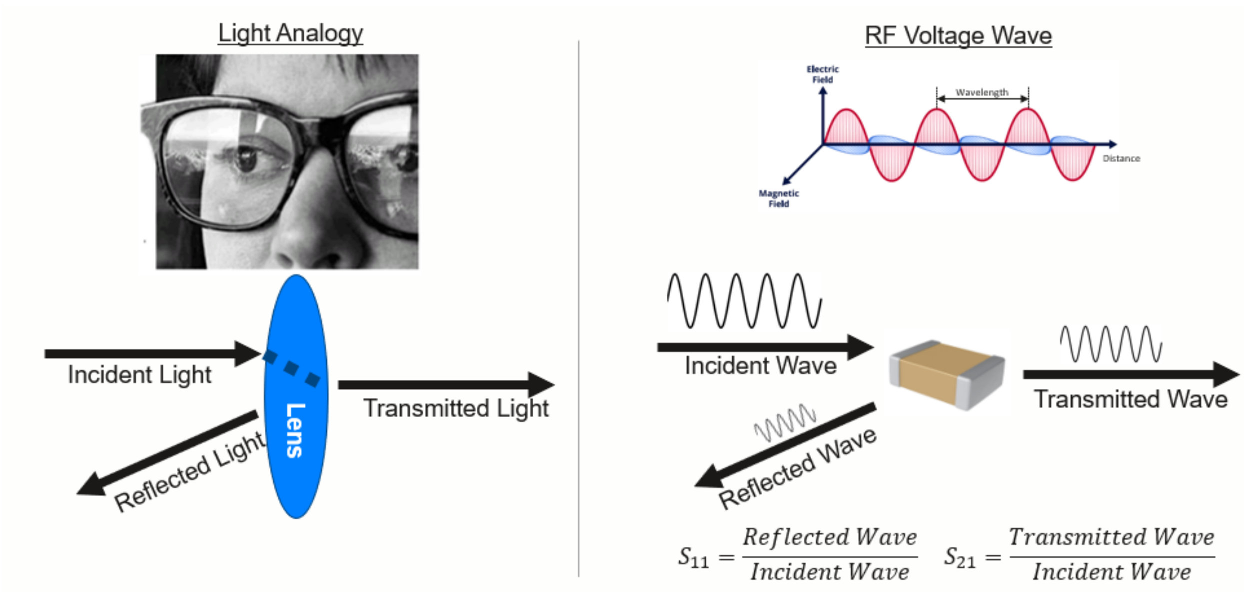
Q or quality factor represents the efficiency of a capacitor and is the ratio of energy stored in a capacitor to the energy dissipated as thermal losses due to the equivalent series resistance (ESR) and I^2R losses. At higher frequencies, higher ESR can cause excessive heating in the capacitor beyond its max allowable power dissipation. Since Q is inversely proportional to ESR, lower ESR at high frequencies will have higher Q at high frequencies. Therefore, higher Q capacitors are preferred by RF designers for high frequency applications.

Q is also related to Dissipation Factor as seen in the equation below. For lower frequency applications, DF is traditionally used instead of Q.

$$Q = \frac{X}{ESR} \qquad Q = \frac{1}{DF}$$

What are S-Parameters and how do I obtain them?

S-Parameters, or scattering parameters are used to describe how RF energy travels through a network (filter, amplifier, capacitor, etc). As an analogy, S-Parameters can be thought of like light traveling through a pair of glasses. Some of the light reflects off the lens towards the source, some light travels through the lens to the eye, and some of the light will be absorbed by the lens. Similarly, RF energy can be thought of as a traveling wave. Some of those waves will bounce back towards the source, some waves will travel through the network, and others will be absorbed. S-Parameters are a convenient way of quantifying those characteristics of the network.



S-Parameters are important in RF design because they are relatively easy to measure and work well at high frequencies versus other parameters that are derived from direct voltage and current measurements. They can be used to not only characterize capacitors, but also inductors, transistors, PCB traces, amplifiers, and even complex systems.

How to obtain S-Parameters for KEMET's CBR series?

S-Parameters are provided as a text-based ASCII file and downloaded from the KEMET website.

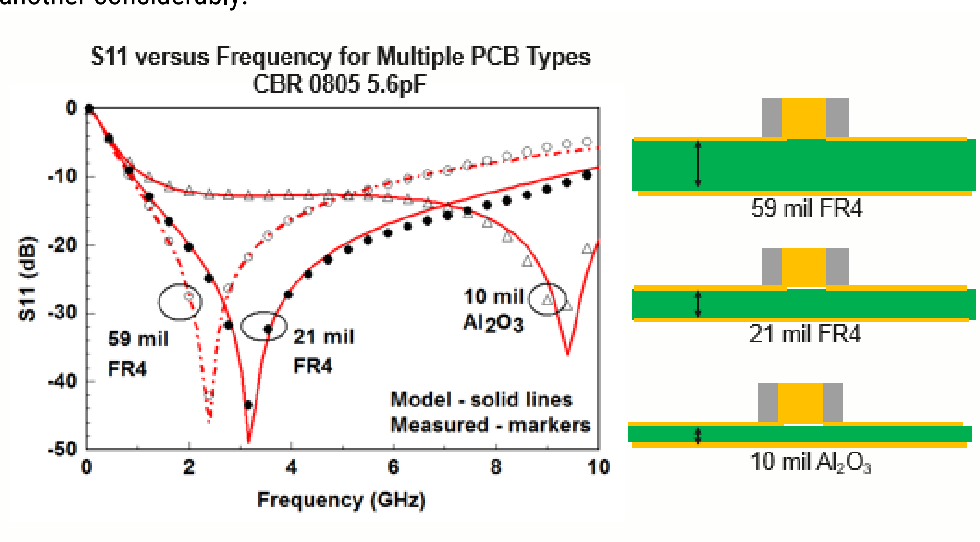
```
!Agilent Technologies,E5071C,MY46109480,A.09.54
!Date: Tue Oct 11 20:23:29 2011
!Data & Calibration Information:
!Freq    S11:SOLT2(ON)    S21:SOLT2(ON)    S12:SOLT2(ON)    S22:SOLT2(ON)
# Hz S dB R 50
50000000      -3.760025e-001  -1.745230e+001  -1.070520e+001  7.279950e+001   -1.070309e+001  7.281087e+001   -3.737441e
74937500      -8.168459e-001  -2.525207e+001  -7.644260e+000  6.481506e+001   -7.641570e+000  6.482366e+001   -8.142310e
99875000      -1.360752e+000  -3.223251e+001  -5.704231e+000  5.780029e+001   -5.702769e+000  5.781035e+001   -1.357891e
124812500     -1.973216e+000  -3.834190e+001  -4.391318e+000  5.161158e+001   -4.389353e+000  5.162188e+001   -1.970618e
149750000     -2.616565e+000  -4.365442e+001  -3.463572e+000  4.626452e+001   -3.460819e+000  4.627317e+001   -2.613514e
```

Do I need to be concerned with PCB and pad dimensions when using RF capacitors?

When MLCCs are mounted to PCBs, the discrete component now becomes a part of an electrical system consisting of other components and materials. The capacitor does not operate independently from the other components and materials, but the overall properties may be influenced by them. When we mount any ceramic capacitor to a PCB, there will be parasitic effects due to the PCB and pad dimensions that need to be considered in the electrical performance. For example, the pad dimensions and ceramic electrodes will have some parasitic capacitance to the ground plane of the PCB and the pad dimensions will have some parasitic capacitance between them. The inductance (or ESL) is also a function of the PCB properties. For example, thinner PCB substrates will cause the inductance to be lower since the ground plane of the PCB acts like a shield of a conductor.

Why is this important?

Since the parasitic capacitances and inductance of MLCCs are relatively low, at low frequencies, it is not much of a concern. Even though the PCB and pad dimensions have some influence of the electrical characteristics, at lower frequencies, they are usually negligible. However, at higher frequencies, these parasitics start influencing the capacitor properties and become a major consideration in the overall design. Here, we can see an example of S11 for a 5.6pF 0805 RF capacitor up to 10GHz mounted on three different PCBs. Notice after about 800MHz, S11 for all three PCBs starts deviating from one another considerably.



This shows just how important taking into consideration PCB conditions can be.

This is one limitation with S-Parameter data. S-Parameters are data taken on a single capacitor measured under a single PCB and pad dimensions. Therefor the actual performance of the RF capacitor can be different from the customers actual use conditions, so designers need to consider the effects of PCB and pad dimensions.

What are Modelithics Models and how do I obtain them?

In order to help customers design in KEMET's CBR RF capacitor series, KEMET has partnered with Modelithics to provide customers with substrate scalable models that can be downloaded and simulated in popular EDA design tools. These measurement-based models allow designers to input capacitance value, tolerance, pad dimensions, and PCB information. The result is a full substrate scalable model that accurately predicts the behavior of the actual PCB performance to achieve first-pass-design-success.
To inquire about obtaining KEMET's Modelithics Models for the CBR series, please visit. (LINK)