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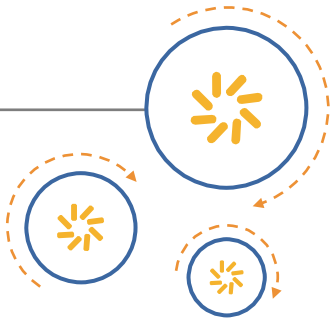

Application Note SAW components

Layout considerations for EPCOS SAW filters

Appnote #24

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Version: 1.1

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Application Note 24
Systems Acoustics Waves

Subject: Layout considerations for EPCOS SAW filters

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Introduction

Surface acoustic wave (SAW) filters are frequency filters, which protect the communication service from interferers and ensure that almost all of the wanted signal will be forwarded to the receiver input or to the antenna.
Not only the SAW filter itself but also the PCB layout has a strong influence on the filter characteristic. This note shows how the layout can improve or harm the filter performance.

Recommended Layout

For some SAW filters (narrow-band) the layout of the corresponding EPCOS evaluation board is included in the datasheet. In most cases an evaluation board with a dielectric height of 1mm is used for applications below 1GHz. For SAW filters having a centre frequency above 1GHz, like in GPS applications, the dielectric height of the RF active layer of most evaluation boards measures 200um.

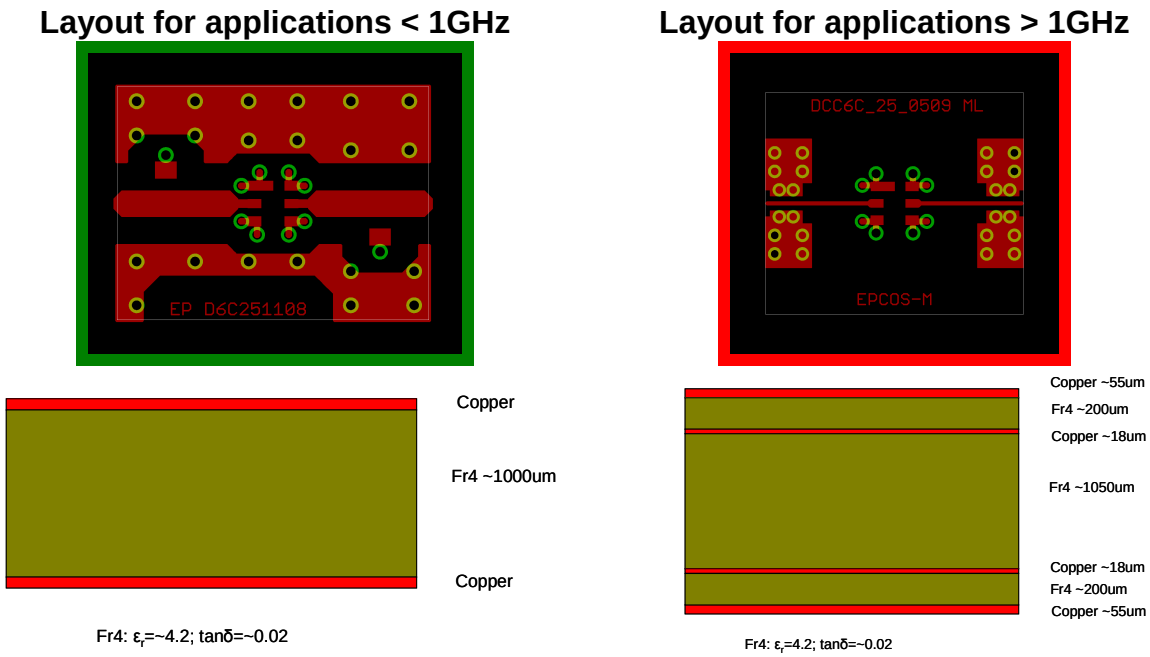


Figure 1: Recommended layout and layer stack for < 1GHz and > 1GHz applications

The diameter of the vias in figure 1 is 24mil (0.6mm). If the layout rules forbid the use of two vias in very narrow distance, we recommend the decrease of via diameter while still using two vias for each ground pad.

SAW filter performance

Two important characteristics of SAW filters are the sensitivity, which corresponds to the insertion attenuation in the pass-band, and the selectivity, which corresponds to the attenuation outside the pass-band.

The sensitivity of the SAW filter itself is almost unaffected by the layout. However, some points have to be considered when creating the layout for SAW filters.

- Too long lines or too thin lines between the SAW filter and adjacent components will add additional losses. Transmission lines should be included into the calculation of the optimum matching network, even for SAW filters with 50Ω input/output impedance. If matching elements are used or if the line length is small compared to the wavelength of the transmitted signal, there is no need for 50Ω transmission lines and a bigger line width can be chosen.

A: Not recommended B: Recommended!

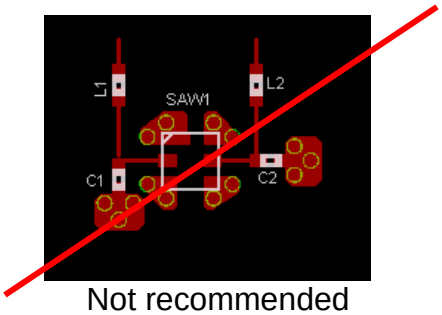
Figure 2A and 2B: Not recommended and recommended line width with 0402 matching components

- Matching simulation results can differ from measurements, if the ground vias are too far away from the pad. At least one via hole should be placed right next to each ground pad.

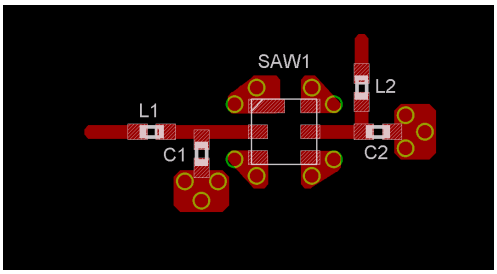
A: Not recommended B: Recommended!

Figure 3A and 3B: Placement of ground vias

In contrast to the sensitivity, the selectivity can heavily be affected by the layout. The out of band attenuation is controlled by the acoustic behaviour of the SAW filter and by electromagnetic effects of both SAW filter and PCB. If signals at out of band frequencies can bypass the SAW filter acoustic structure, we defined it as crosstalk. To avoid harmful crosstalk, place inductors, especially wirewound inductors, orthogonal in order to reduce magnetic coupling.



Not recommended

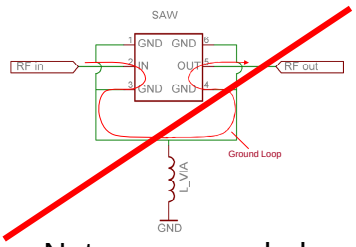


Recommended!

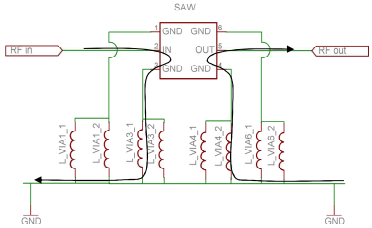
Figure 4A and Figure 4B: Not recommended and recommended placement of inductors

There is also an unpredictable effect of the orientation of multilayer inductors. Multilayer inductors have at one side a marked line to indicate the winding direction. If the orientation of the inductors can be taken into account in production, its influence can be examined, too.

Concerning the routing of signal lines and the via placement three different phenomena do occur.
1. Capacitive coupling
If two separated conducting materials, like signal lines or ground planes, are at different potentials, an electrical field is built up.
It is important to minimise the electrical field between input and output signal lines.
2. Magnetic coupling
If a current flows, there will be a magnetic field. The effect of magnetic coupling is strong if signal lines are routed in parallel.
3. Galvanic isolation – ground loops
Here it is observed, if the current of the input signal flows to the output. The easier it is for the current to flow back where “it comes from”, the better is the out of band attenuation.



Not recommended



Recommended!

Figure 5A and Figure 5B: Ground loops (5A) and recommended current flows (5B)

It is not always clear which phenomenon dominates. The measurements presented below give an idea of the influence of these phenomena.

Measurements

Open and short measurements show the maximum crosstalk levels caused by the signal lines due to capacitive coupling and magnetic coupling. If the measurement shows worse attenuation, this is caused by the improper grounding of the SAW filter or by the SAW filter itself.

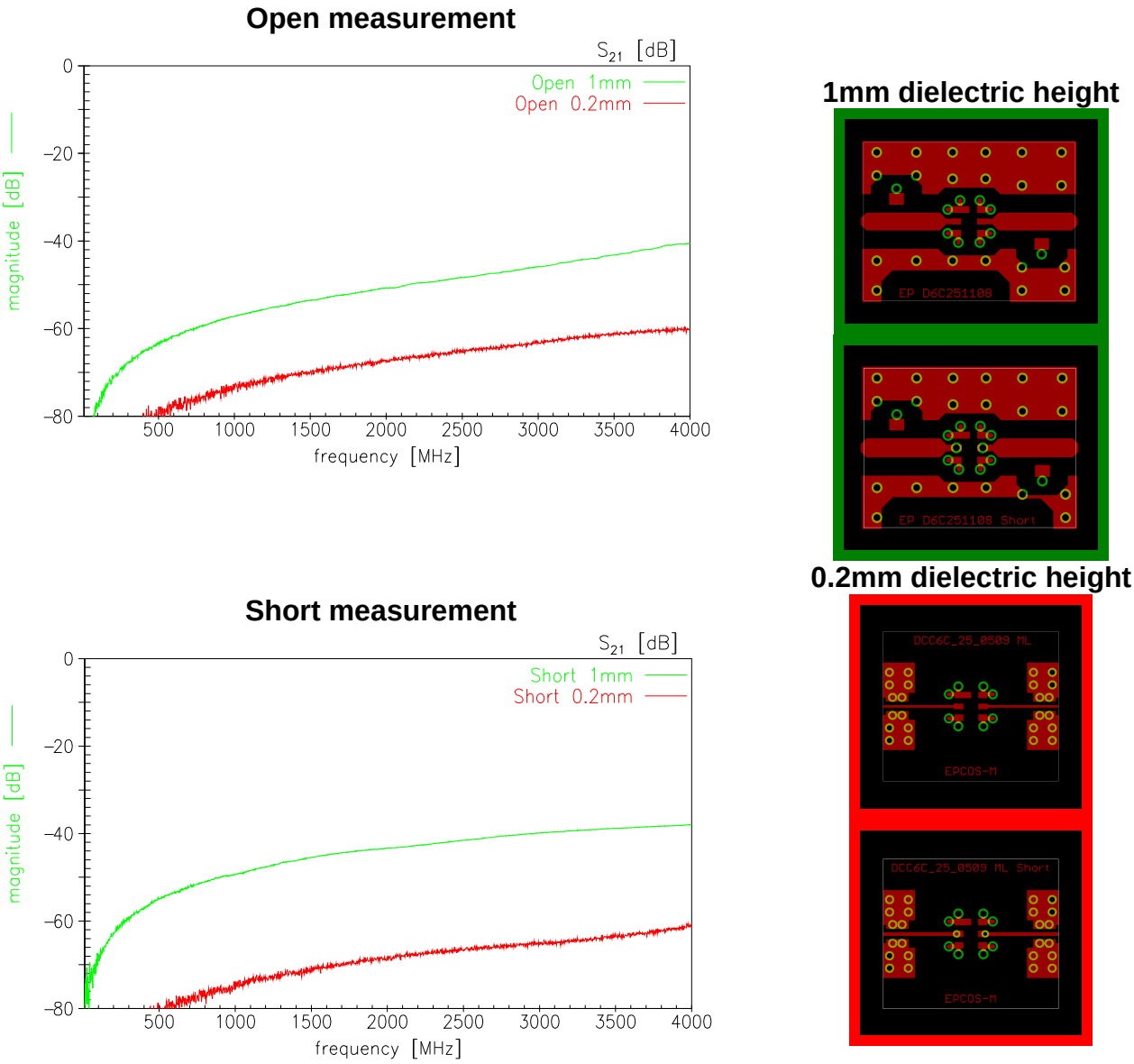


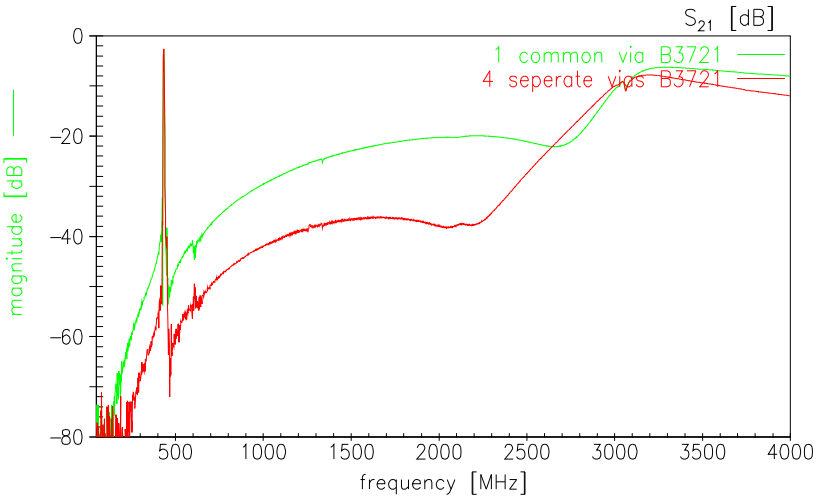
Figure 6: Open and short measurements for crosstalk evaluation of signal lines

Figure 6 shows that the crosstalk of the signal lines gets important for a 1mm layer stack at higher frequencies.

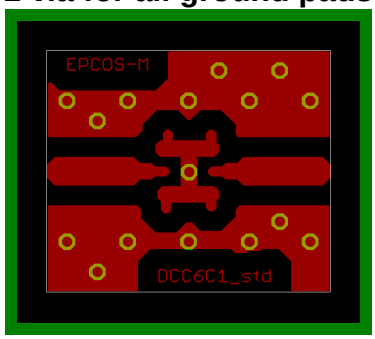
Effect of ground loops

Ground loops are created if ground pins from the input port and the output port are connected on the top side of the PCB and fed to the system ground plane by a single common via – see green framed layout. To avoid the common ground path, the ground pins of the input and output ports are fed to the system ground plane (bottom PCB plane) by their own vias – see red framed layout. The port ground pins are isolated from the upper ground plane to avoid the ground loops at the PCB top side.

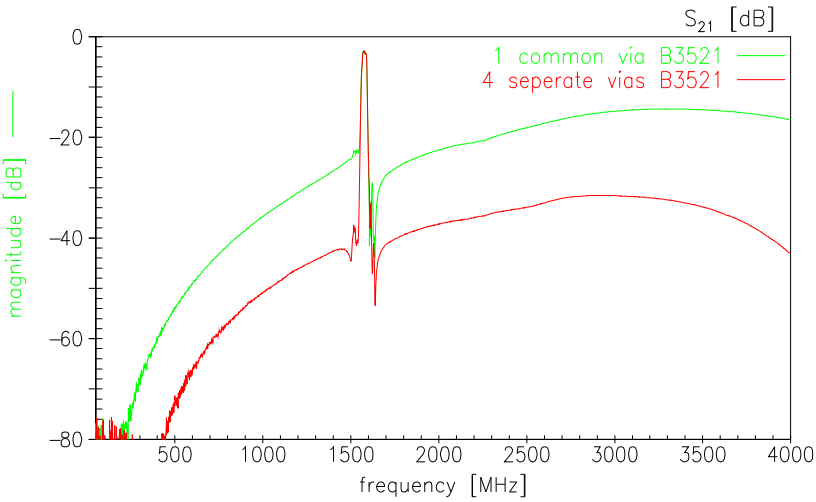
B3721 – 315 MHz wide band filter



1 via for all ground pads



B3521 – 1575 MHz wide band filter



separate grounding for each ground pad

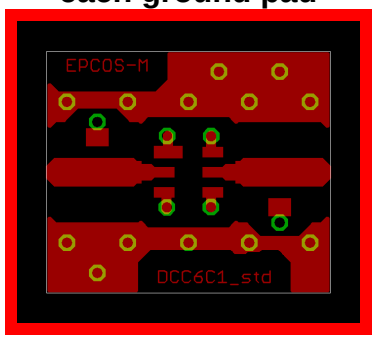
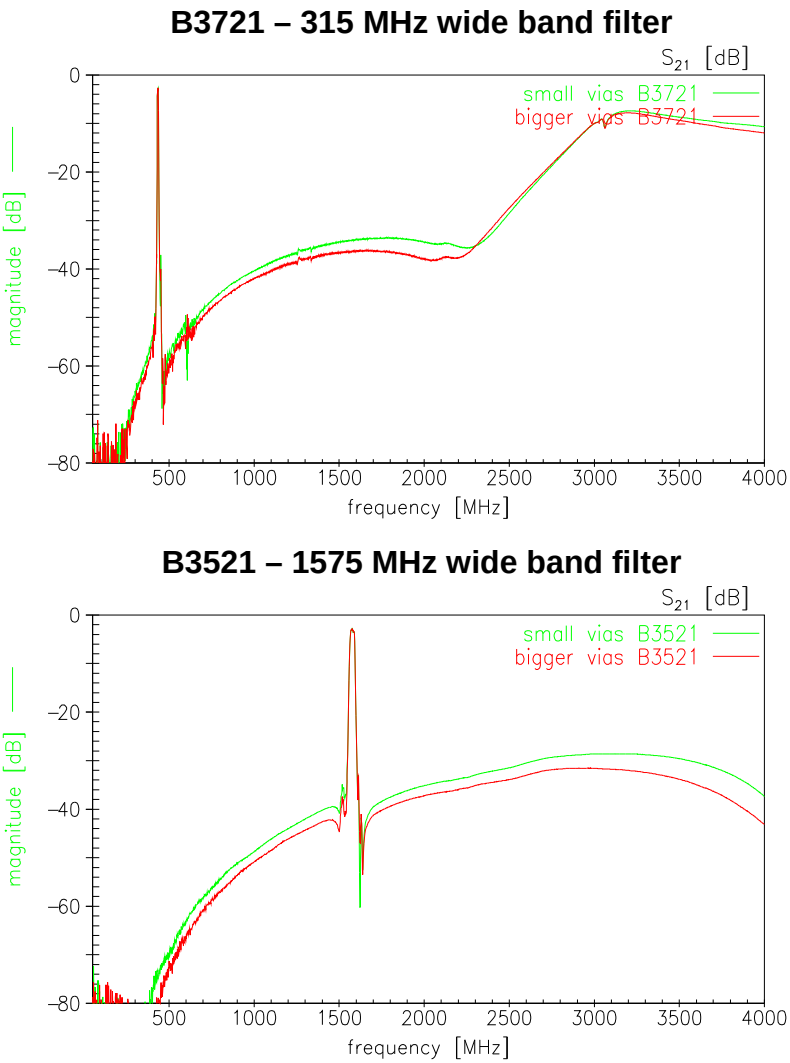


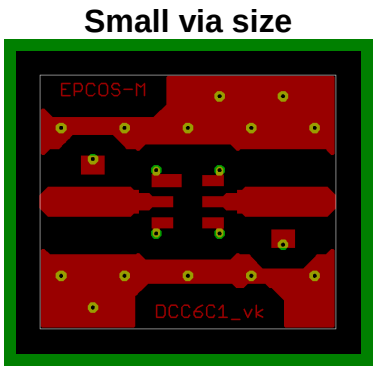
Figure 7: Harmful effects of ground loops caused by using only one ground via

Ground loops can deteriorate the high attenuation of SAW filters. Therefore we recommend assigning separate ground vias for each ground pad.

Effect of via size

In order to have a good grounding of SAW filters the resistance and the length of the connection between ground pads of the SAW filter and the ground plane should be as small as possible. The connection is realised by vias. The via resistance corresponds to the diameter of the vias holes.





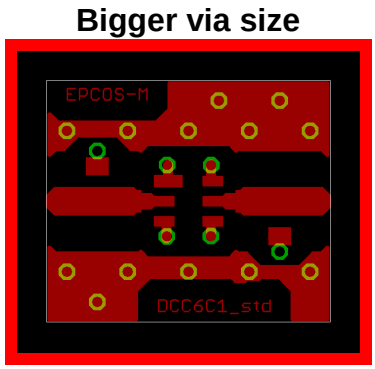


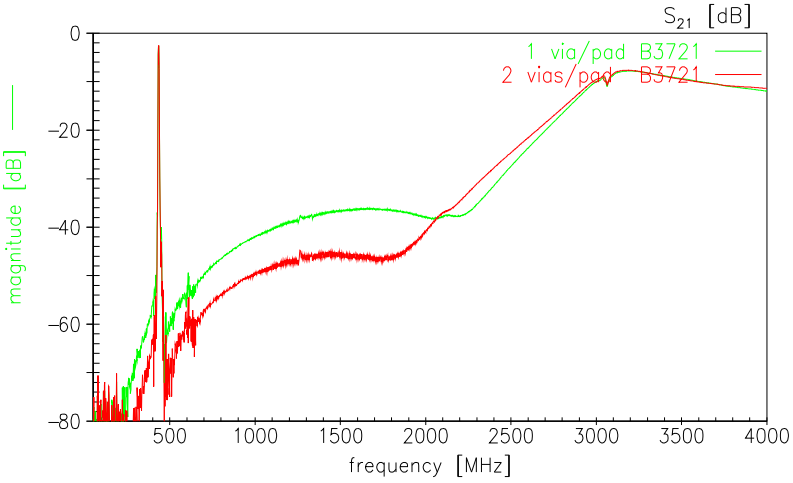
Figure 8: Influence of the diameter of the via hole

If the via diameter shrinks from 24mil (0.6mm) to 8mil (0.2mm), the out of band attenuation is decreased by some dB.
Especially in layouts for SAW filters having a centre frequency higher than 1GHz the via diameter should not be chosen too small.

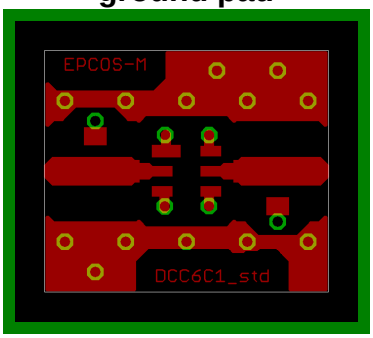
Effects of the number of vias

An increase of the number of vias will improve the connection between SAW filter ground pads and the ground plane. Furthermore the galvanic isolation will be improved, when vias are placed close to the signal line.

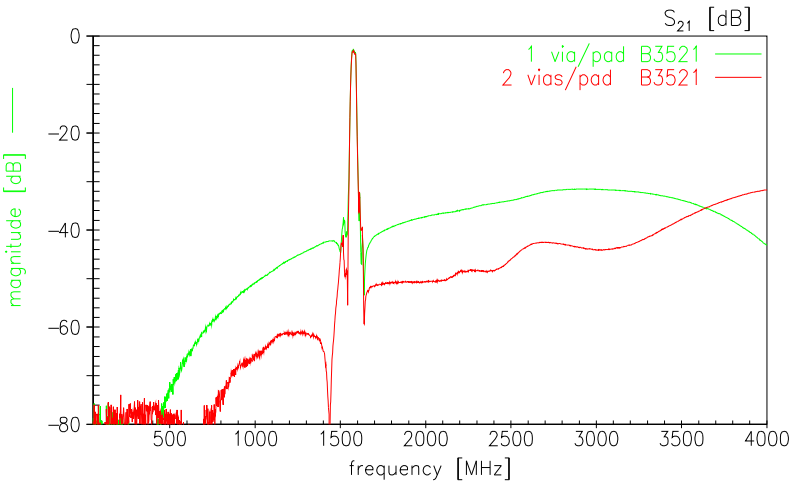
B3721 – 315 MHz wide band filter



1 via for each ground pad



B3521 – 1575 MHz wide band filter



2 vias for each ground pad

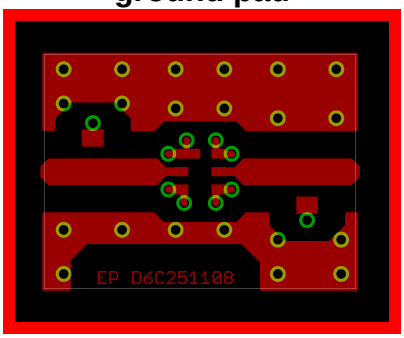


Figure 9: Improved selectivity by the means of two vias per ground pad – at least one of them close to the microstrip line

Using two vias for each ground pad clearly improves the selectivity. Therefore we strongly recommend using two vias for each ground pad.

Effects of the dielectric height

The dielectric height is one factor which determines the influence of the magnetic and capacitive coupling of the microstrip lines. The shorter the distance between the ground plane and the microstrip line the less electrical-magnetically fields radiate.

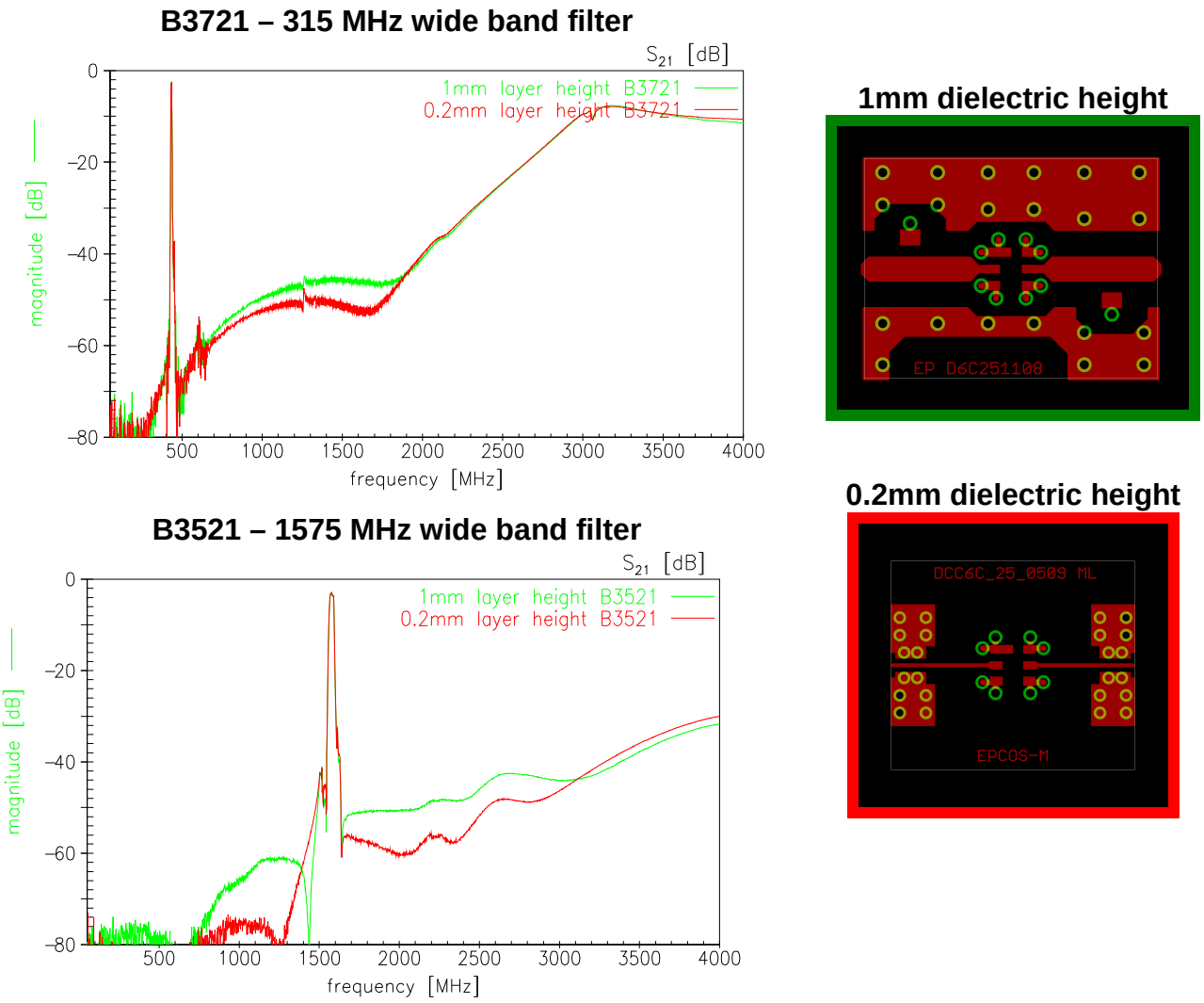


Figure 10: Influence of the dielectric height

In accordance with the PCB open and short measurements the dielectric height is important for attenuation levels ~-50dB and for frequencies above 1GHz.

Conclusion

The measurements show that the layout has a strong influence on the out of band attenuation. In order to avoid harmful effects like ground loops we recommend using 2 vias for each ground pad.
The influence of the layout is getting stronger with higher frequencies. That is why EPCOS is preferable using 0.2mm dielectric layer heights for the RF active layer for SAW filters having their centre frequency above 1GHz. EPCOS evaluation boards for SAW filters with centre frequencies below 1 GHz have in general 1mm dielectric layer heights. One can assume that decreasing the dielectric layer height will improve the out of band attenuation if all other layout recommendations are respected.