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by Paul Reid p.28

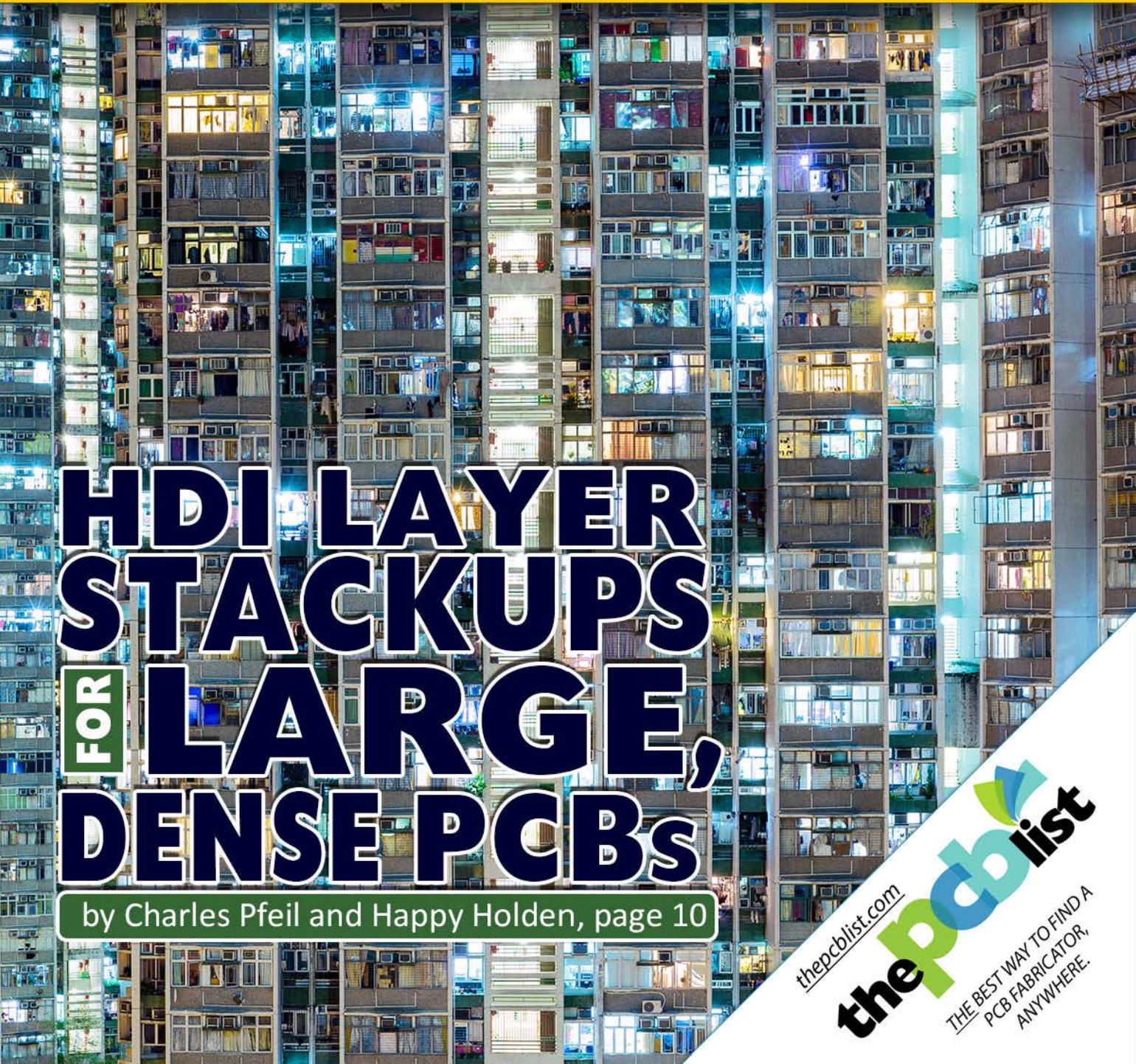
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by Kenneth MacCallum p.38

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by Charles Pfeil and Happy Holden, page 10

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Making a Connection with Conductor Discontinuities

by **John Coonrod**
ROGERS CORPORATION

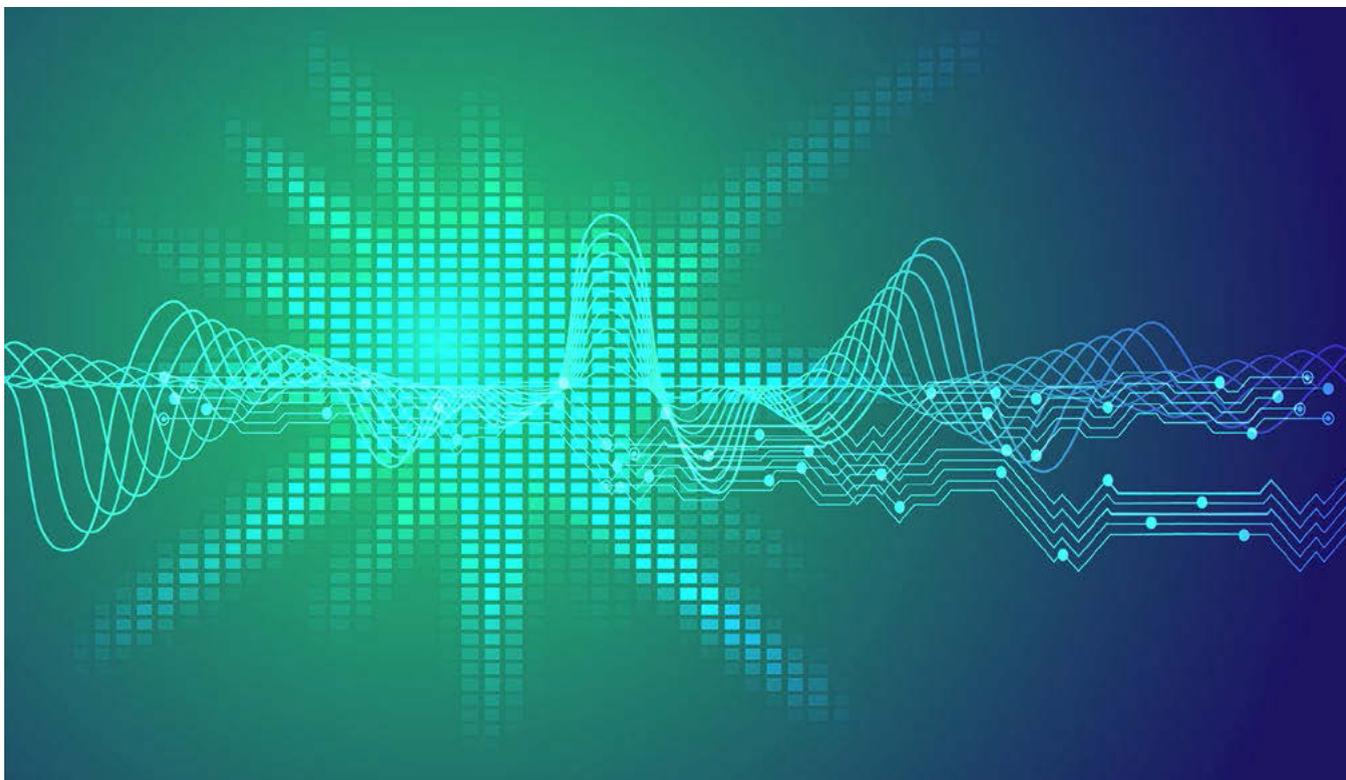
The title may be confusing for many technologists accustomed to dealing with electrical issues in traditional PCBs, but if you design PCBs that operate at microwave frequencies, it makes perfect sense. With microwave PCB design, it is not uncommon to have a conductor run come to a stop, followed by a space, followed by another conductor run, with the RF energy propagating through the discontinuity without the slightest problem. .

Not Your Traditional Design

In traditional PCB design world, this conductor-space-conductor configuration is called an “open,” and it is considered a reject that yields a dead circuit. But microwave PCB design is much different. How does RF energy propa-

gate through conductor discontinuities in microwave PCBs?

When considering microwave technology, it is all about waves. Specifically, it is the electromagnetic (EM) wave that propagates on the PCB, and the wave properties are manipulated by the PCB design to get the desired circuit performance. To picture a simple example of an EM plane wave on a PCB, you can think of the wave in a cross-sectional view that looks like a sine wave. This sine wave will have different locations with high and low energy and $\frac{1}{4}$ of the sine wave is one of the maximum power points. A $\frac{1}{2}$ sine wave is where the wave returns to zero and has no energy. These fractions of the sine wave are appropriately called $\frac{1}{4}$ wavelength and $\frac{1}{2}$ wavelength, respectively.



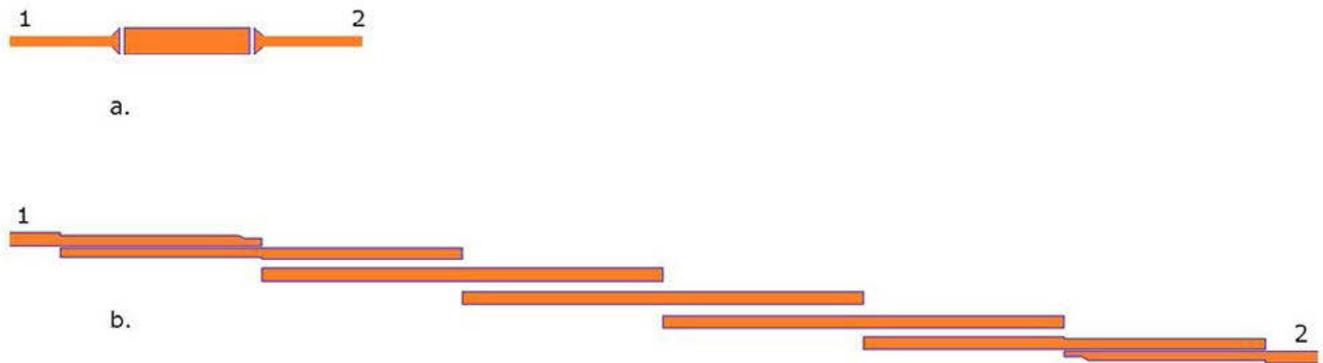
MAKING A CONNECTION WITH CONDUCTOR DISCONTINUITIES *continues*

Figure 1: Shown is the signal layer of a microstrip (a) gap coupled resonator and (b) edge coupled bandpass filter.

At microwave frequencies, a resonator can be made by using a conductor with a physical length that is exactly $\frac{1}{2}$ wavelength of the wave on the circuit. This $\frac{1}{2}$ wavelength conductor will resonate, which is accomplished by a wave that bounces back and forth and sets up a standing wave. The standing wave generates a lot of energy and resonates at the frequency associated with that $\frac{1}{2}$ wavelength.

The big question is this: How do you get the energy on the conductor that is acting like a $\frac{1}{2}$ wavelength resonator? If you have a conductor that connects to the $\frac{1}{2}$ wavelength resonator, that combination creates a much longer conductor, and it no longer works as a $\frac{1}{2}$ wavelength resonator. This means that you cannot directly connect to the resonator conductor and you will need to “couple” energy to the resonator. This is done by using feed line conductors on both sides of the $\frac{1}{2}$ wavelength conductor, which are physically very close to the resonator conductor; as a result, the energy on the feed lines will have electric fields that radiate onto the resonator.

The radiated fields will couple electric energy onto the resonator, and now the conductor that is $\frac{1}{2}$ wavelength long will resonate. An example of a $\frac{1}{2}$ wavelength resonator, with feed lines on both sides of it, is shown in Figure 1a.

Filtering Frequencies

Let's take this idea and expand it to make a filter. This filter example will only let energy pass from a band (range) of frequencies, and is

known as a bandpass filter. Due to the nature of the resonator, it is very frequency-dependent; in other words, the resonator will have a lot of energy only at a narrow range of frequencies. The tight range of frequencies for resonance is based on the physical length of the conductor being a $\frac{1}{2}$ wavelength.

To illustrate, if higher frequencies are considered, the wavelength of that energy is shorter and the physical length of the resonator conductor is not correct for those frequencies that will not allow resonance. However, if you put together (couple) several resonators that are slightly different, they will resonate within a band of frequencies and let energy through within that range of frequencies. The resonators will not resonate outside of the frequencies of which they are the correct size, so the energy from those frequencies will be shut off. The resonators in our filter example will be put side-by-side so they can couple energy better from one resonator to the other, as shown in Figure 1b.

The best way to view the electrical performance of the bandpass filter is to show how much energy is passed through the filter and how much is rejected by the filter, when considering a wide range of frequencies. One method of doing this is by using a network analyzer and showing the S21 curve over a range of frequencies. The S21 parameter is a scattering (S) parameter, which basically shows how much of the energy that arrives at port 2 came out of port 1. . It can be thought of as input and output for port 1 and 2 respectively, as shown in Figures 1a and

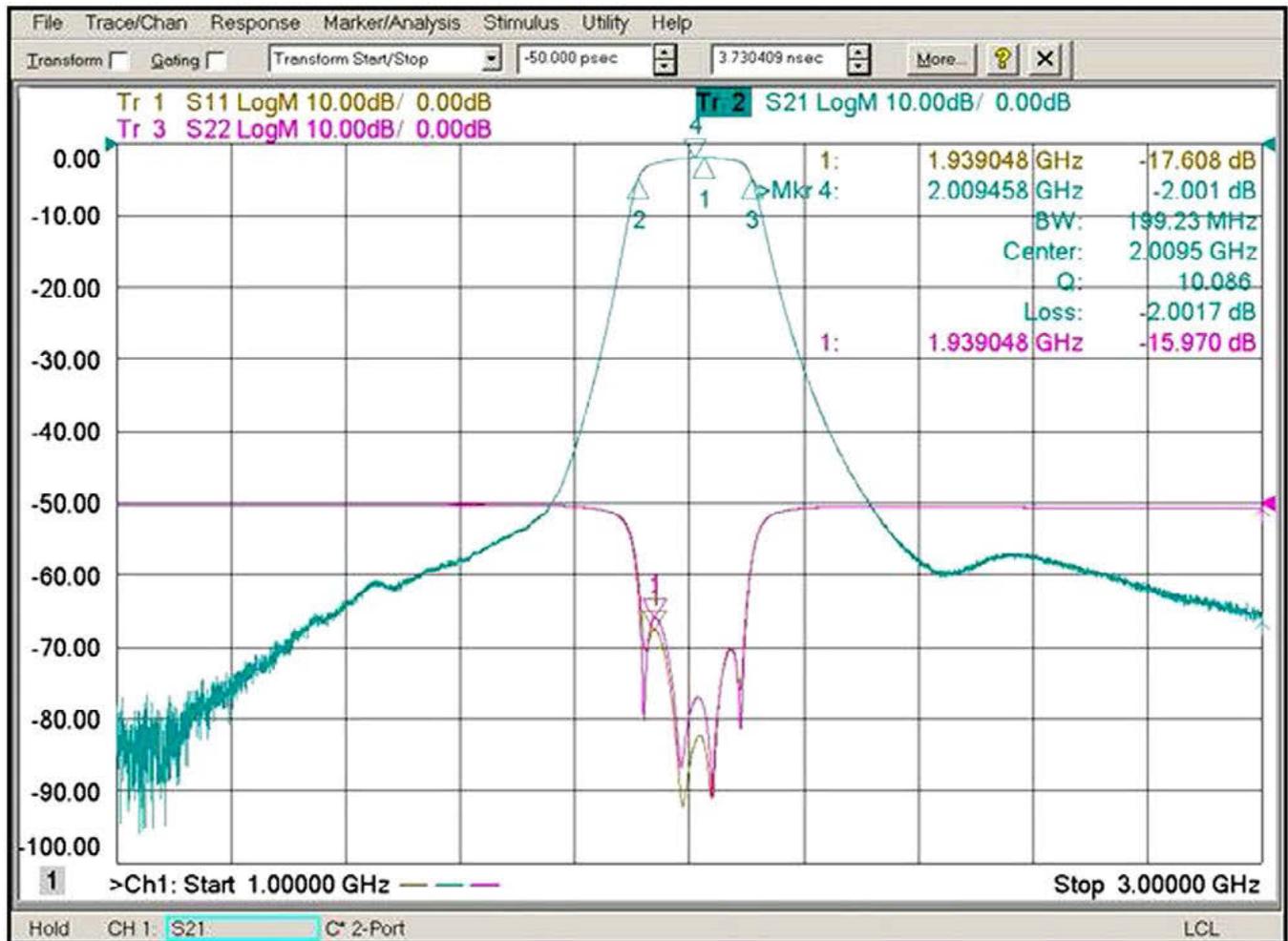


Figure 2: Frequency vs. S21 performance of a microstrip edge-coupled bandpass filter.

1b. A frequency-S21 curve for a microstrip edge-coupled bandpass filter is shown in Figure 2.

Even though there are multiple conductor discontinuities for the filter shown in Figure 1b, it can be seen that energy still propagates through this structure, given the energy is at the right frequency. In the case of the edge-coupled filter performance shown in Figure 2, a good example would have energy propagate through the filter at 2 GHz. The blue curve in Figure 2 shows S21 performance, and there is a band of frequencies, from about 1.9 to 2.1 GHz, at which much of the energy is passed through the filter. If an application was generating a lot of energy at 3 GHz (the far right frequency in Figure 2), the energy at that frequency is pretty much shut off with about 65 dB of loss.

Summary

Contrary to many of the concepts related to traditional PCBs, conductor discontinuities at microwave frequencies may not cause a defect in a circuit, and they could actually be the reason the circuit is performing properly. Additionally, there are many other design issues to consider when designing microwave PCB circuitry, and the rules regarding typical PCBs no longer apply. **PCBDESIGN**



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