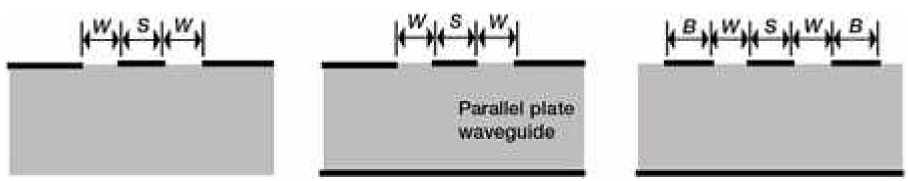
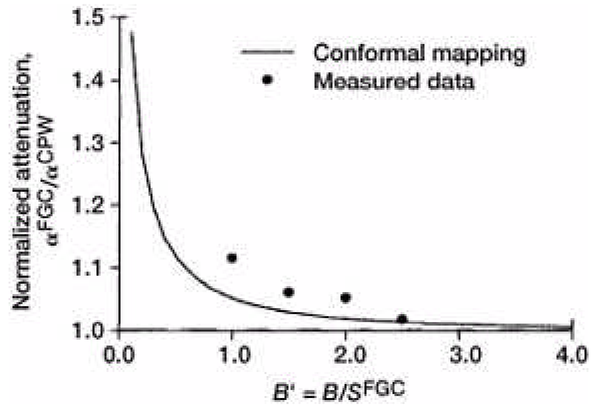
Finite Ground Coplanar (FGC) Waveguide: Characteristics and Advantages Evaluated for Radiofrequency and Wireless Communication Circuits

Researchers in NASA Lewis Research Center's Electron Device Technology Branch are developing transmission lines for radiofrequency and wireless circuits that are more efficient, smaller, and make lower cost circuits possible. Traditionally, radiofrequency and wireless circuits have employed a microstrip or coplanar waveguide to interconnect the various electrical elements that comprise a circuit. Although a coplanar waveguide (CPW) is widely viewed as better than a microstrip for most applications, it too has problems. To solve these problems, NASA Lewis and the University of Michigan developed a new version of a coplanar waveguide with electrically narrow ground planes. This new transmission line, which we call the finite ground coplanar (FGC) waveguide, is illustrated in the following figure.



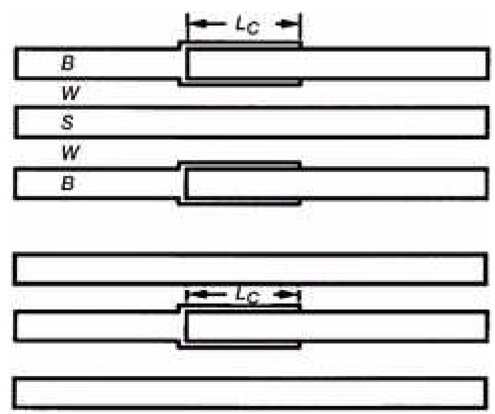
Coplanar waveguides. Waveguide width, W; center conductor width, S; ground plane width, B. Left: Conventional coplanar waveguide. Center: Waveguide with lower ground plane. Right: Finite ground coplanar waveguide.

Through extensive numerical modeling and experimental measurements, we have characterized the propagation constant of the FGC waveguide, the lumped and distributed circuit elements integrated in the FGC waveguide, and the coupling between parallel transmission lines. Although the attenuation per unit length is higher for the FGC waveguide because of higher conductor loss, the attenuation is comparable when the ground plane width is twice the center conductor width as shown in the following graph. An upper limit to the line width is derived from observations that when the total line width is greater than $\lambda_d/2$, spurious resonances due to the parallel plate waveguide mode are established. Thus, the ground plane width must be less than $\lambda_d/4$ where λ_d is the wavelength in the dielectric. Since the center conductor width S is typically less than $\lambda/10$ to maintain good transverse electromagnetic mode characteristics, it follows that a ground plane width of $B = 2S$ would also be electrically narrow. Thus, we can now treat the ground strips of the FGC waveguide the same way that the center conductor is treated.



Attenuation, a*, of FGC waveguide with S = W = 25* mm *normalized to the attenuation of a conventional CPW with S = W = 25* mm *as a function of the normalized ground plane width, B, where S is the center conductor width and W is the waveguide width.*

This allows the novel integration of circuit elements in the FGC waveguide. To explore this, researchers integrated metal-insulator-metal (MIM) capacitors, inductors, and thin film resistors into the center conductor and the ground planes of the transmission line as illustrated in the final figure. Results indicate that even though the value of the parasitic reactance associated with each element is independent of the element placement, the value of the primary element value (capacitance, inductance, and resistance, respectively) does vary upon placement. Specifically, when two elements are connected in the ground planes as shown in the drawing, they add in parallel. Thus, capacitors in the ground planes can be made shorter and still provide the same capacitance as capacitors placed in the center conductor. Furthermore, since the parasitic reactance is independent of element placement, the self-resonant frequency of the capacitors in the ground planes is higher.



MIM capacitor. Center conductor width, S; waveguide width, W; ground plane width, B; capacitor length, L_C. Top: Integrated in ground planes. Bottom: Integrated in center conductor of the FGC waveguide.

Lastly, coupling is reduced as the ground plane width is reduced while the distance between the center of each line is kept constant. Furthermore, the coupling between parallel transmission lines is lower for the FGC waveguide than for the conventional coplanar waveguide. In fact, even a small slot between the ground planes of the conventional coplanar waveguide can lower coupling by 10 dB.

All these results indicate that the FGC waveguide is a better transmission line than the coplanar waveguide and the microstrip for radiofrequency and wireless circuits. Further work is underway to more fully develop design rules for this new transmission line.

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