

With a microstrip structure, why does the return current flow in the ground plane on a path under the signal track?

An elegant arrangement exists which is the result of inductive coupling and a low impedance path.

A magnetic field exists around any current carrying conductor; any change in the current flow produces a proportional change in the magnetic field and this change induces an e.m.f. in the conductor itself (self-inductance) and any other nearby conductors (mutual inductance). The coupling tends to increase with frequency, since the induced voltage is proportional to the rate of change of magnetic field.

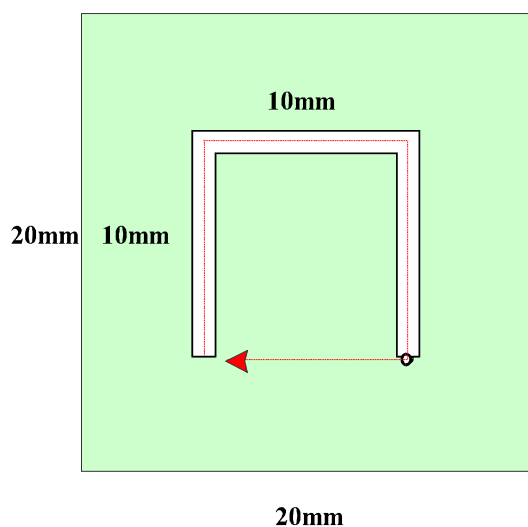
The presence of a ground plane effectively reduces the loop area of circuits by ensuring that the return current flows under the signal conductor. This occurs at high frequencies due to the field around the signal conductor inducing a current in the ground plane directly below it.

(The following has been extracted in part from “Practical Simulation of Circuit Boards and related structures by K. J. Scott; ISBN 0 86380 161 7. Section 6.5, Current Flow in Ground Conductors).

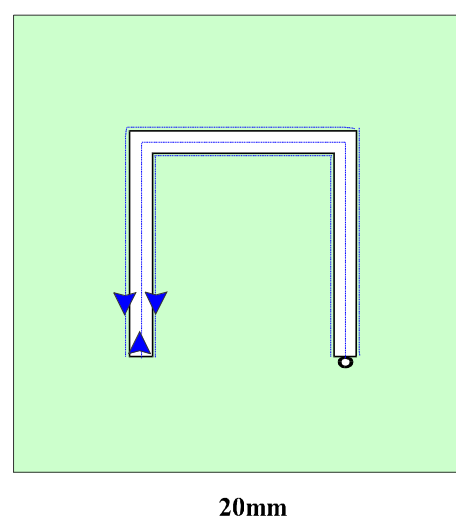
Consider a simple U shaped track over a finite ground plane as below. The substrate thickness is 1mm with a dielectric constant of 5. The track and ground plane metalisation is copper with a thickness of 15um and a sheet resistance of 1.15mOhm per sq. One end of the track is connected to the ground with a via and the other is fed with a voltage source.

The current will take the path of lowest impedance.

Current loop at 1KHz.



Current loop at 1MHz.



Resistance and self-inductance of the relative loop path lengths are:

$$R = 36.8\text{mOhms.}$$

$$L = 17.5\text{nH}$$

$R = 42.5\text{mOhms}$ (A higher value due to longer path length and skin effect)

$L = 12.1\text{nH}$ (A lower value due to mutual coupling and smaller loop).

At 1KHz the red path has a negligible inductive reactance of $X_L = 0.11\text{mOhms}$.

The current follows the red path, because it has the lowest resistive value.

At 1MHz however the inductive component of impedance dominates, and the inductive reactance for the red path would increase by a thousand times to $X_L = 110\text{mOhms}$.

The current then prefers to return under the trace following the blue path, which has an inductive reactance of $X_L = 76\text{mOhms}$.

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Examples

