

Impact of Metal Fill on On-Chip Interconnect Performance

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Abstract—In Chemical Mechanical Polishing (CMP) employed in advanced IC fabrication processes, dummy metal fill structures are added in the low metal density areas to achieve global uniformity. It is important to study the impact of metal fills on on-chip transmission line structures as these topologies are gaining more importance for longer interconnections in high speed, low power VLSI designs. The addition of floating or grounded metal fills leads to capacitive and inductive parasitic loading of interconnects. This in turn results in impedance mismatches, increased delay, dispersion and increased loss. This paper deals with the analysis of on-chip interconnects considering metal fills. The first contribution of this work is to show the effects of metal fills on transmission line characteristics. We show the change in frequency dependent behavior of characteristic impedance and propagation constant when metal fills are inserted. We further study the impact of metal fill placement, feature size and shape on the transmission line characteristics. We show that for a $\sim 50\%$ metal density, $9\mu\text{m} \times 9\mu\text{m}$ metal fill increases the distributed capacitance by $\sim 30\%$ and distributed resistance by $\sim 29\%$. In comparison, smaller metal fills of $3\mu\text{m} \times 3\mu\text{m}$ result in a distributed capacitance increase of $\sim 20\%$ and distributed line resistance increase of $\sim 19\%$ for the same metal density. Octagonal metal fill for the same metal fill area ($81\mu\text{m}^2$) improves the performance by reducing the capacitive impact to $\sim 26\%$ and loss impact to $\sim 16\%$. This work concludes with design recommendations for on-chip transmission lines considering metal fills.

Index Terms—CMP, metal fill, microstrip, transmission lines.

1 INTRODUCTION

ADVANCED IC manufacturing processes employ Chemical Mechanical Polishing (CMP) to planarize metal and dielectric layers [1]. CMP alone provides good local uniformity but does not guarantee global uniformity. However, CMP in conjunction with a metal density rule improves global uniformity. The metal density rule requires adding dummy metal fill structures in areas of low metal density. Metal fill is gaining ever increasing attention in on-chip interconnects and circuit designs from the IC fabrication yields as well as electrical parasitic impacts perspectives. The electromagnetic effects of metal fill could potentially cause issues in timing and noise margins, and losses/mismatches in interconnect and components. Therefore, metal fill parasitic effects and their mitigation is an important topic of research. With further technology scaling and advanced processing technologies, the impact of metal fills on circuit performance is expected to increase [2]. This highlights the need for including the electromagnetic effects of metal fill in the design phase.

In recent years, a lot of studies have given electrical consideration to metal fills: modeling of the parasitics, minimizing the impact, utilizing metal fill structures and algorithms for efficient implementations. The additional metal fill results in parasitic capacitance and added loss in interconnects and passive components. This causes or worsens mismatches in critical circuit blocks [3]. The

impact of metal fills on delay and cross-talk noise has been studied e.g. in [4] demonstrating the influence of metal fill on integrated circuit performance and reliability. [5] focuses on the parasitic capacitance and resulting crosstalk and delay. Tsuchiya et al. [6] have considered high frequency eddy-current losses in metal fills and their impact on the characteristics of transmission lines [7]. The work in [8] discusses different techniques to reduce the coupling capacitance between two signal lines such as increasing buffer distance and using orthogonal metal fill lines. This work also proposes a curve-fitted capacitance formula for the different cases considered. [9] provides a combined study of metal fill parasitics and stress increase in low-k dielectrics due to metal fill insertion between two lines. This demonstrates the impact of size of the metal fill on stress and capacitance. The authors propose rounded corners to reduce both effects. In terms of metal fill implementations, several algorithms have been proposed based on the coupling/parasitic constraints of the metal fills [10], [11], [12]. Actively utilizing metal fill structures has been suggested as well. For example, Gaskill et al. [13] have proposed an isolation enhancement technique with patterned ground metal fills. Also, [14] suggests to create additional capacitance with metal fills as part of the power delivery network's decoupling capacitance. The research in [15] compares loss and time delay for different metal fills sizes and alignment for strip-line transmission line structures. The conclusions of this study change based on the

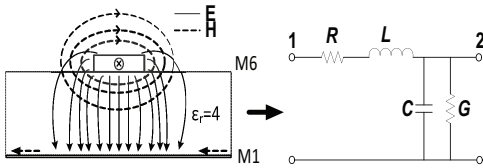


Fig. 1: Microstrip line conceptual electric field lines E and magnetic field lines H .

alignment of the metal fill relative to the transmission line.

Our work is focused on exploring different design aspects of metal fill for microstrip line structures. Section 2 provides the details of the electromagnetic effects after metal fill is inserted. Section 3 considers the maximum buffer distance possible with metal fill in a given process. Our methodology and setup are discussed in Section 4. Section 5 discusses the results for different metal fill design aspects and their impact on the transmission line parameters. These metal fill design aspects include placement, size and shape. Finally, Section 6 concludes the work with design recommendations and discussion of future work.

2 THEORY OF METAL FILL IMPACT ON T-LINE

To understand the impact of additional floating or grounded metal fill on a microstrip transmission line structure, it is helpful to first consider the electromagnetic fields without any metal fill. The line is usually laid on the top metal layer (M6) to reduce losses. Consider a 2D case with a quasi-TEM wave propagation mode. Fig. 1 shows an illustration of the electric field and magnetic field lines together with an equivalent distributed RLGC model for the structure [16]. The electric fields generated by the microstrip conductor can be divided into two regions: 1) parallel plate fields; 2) fringing fields. It is helpful to consider these regions when discerning metal fill impact.

The addition of floating metal fills in a microstrip's electric field causes polarization of the metal fills and changes the capacitance between the transmission line and ground conductor. Also, time varying magnetic fields interacting with the metal fill create eddy current loops, which cause ohmic losses. These electromagnetic effects are ultimately reflected back as an increase in per unit length (p.u.l.) resistance (R), decrease in p.u.l. inductance (L), and increase in p.u.l. capacitance (C) parameters. The following explains the physical behavior of electromagnetic fields after metal fill insertion. The explanation is given separately in terms of electric impact and magnetic impact.

2.1 Electric Impact

Given small size of the metal fill compared to the wavelength at the maximum operating frequency, the metal fill conductor can be assumed to be at a constant

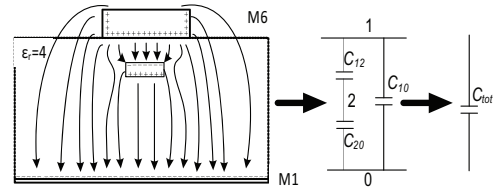


Fig. 2: Conceptual change in E due to metal fill in parallel plate field.

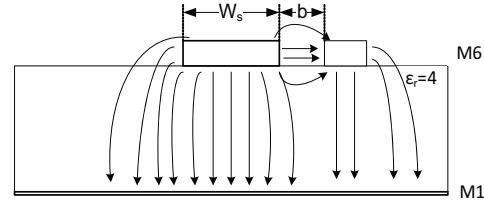


Fig. 3: Conceptual change in E due to metal fill in fringe field.

potential and parasitic capacitance can be determined from quasi-static considerations. The insertion of floating metal causes a change in the electric field as demonstrated in Figs. 2 and 3. The induced surface charges result in additional parasitic capacitance. This additional capacitance depends on the new electric field, metal fill dimensions and placement relative to the microstrip line. The impact of metal fill placed in the parallel field region is different than that in the fringing field region. When a floating metal fill is placed inside the parallel fields, the metal fill polarizes with negative induced charges on the top and positive charges on the bottom, as illustrated in Fig. 2. This leads to an increase in overall capacitance. When the metal fill is placed away from the main line, the electric field between the metal fill and the microstrip line reduces, and this results in reduced additional capacitance. If the metal fill is grounded, the field lines terminate on the metal fill since there is no potential difference with the ground plane. This leads to a significantly larger amount of capacitance (no C_{20}) in the equivalent circuit. When metal fills are added onto the same metal layer as that of the microstrip, the metal comes in the fringing field region. Since the fringing fields are not as strong as the parallel fields underneath the microstrip line, the impact of these metal fills is smaller. Fig. 3 illustrates the changes in electric fields due to in-plane metal fill.

2.2 Magnetic Impact

As shown in Fig. 1, since the dielectric and air magnetic properties are similar, the magnetic field lines are unaffected by the dielectric material underneath. When metal fill is inserted in these field lines, at low frequencies, there is negligible change. The time varying magnetic flux through the metal fill induces an emf, which will result in eddy current loops. As frequency increases, these eddy current loops generate a larger H

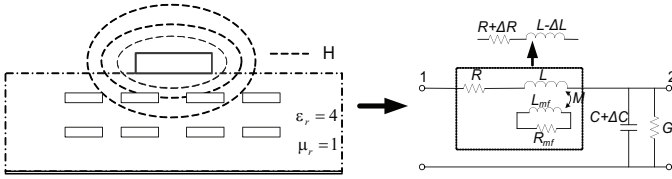


Fig. 4: Magnetic impact of metal fill and equivalent circuit representation.

field in an opposing direction, as per Lenz's law. These magnetic fields reduce the total stored magnetic energy and, hence, inductance starts to drop at these higher frequencies. Eddy current losses also increase the per unit length resistance. [6] demonstrates the analytical estimation of these eddy current losses due to metal fill. As shown in Fig. 4, R_{mf} and L_{mf} are the distributed parasitics due to magnetic effects. The ΔR increase in per unit length resistance can be given by (1) [6]

$$\Delta R = R_{mf} \left(\frac{\omega^2 M^2}{R_{mf}^2 + \omega^2 L_{mf}^2} \right) \quad (1)$$

and a frequency dependent R_{mf} can be given as in (2) [6]

$$R_{mf} = \rho \left(\frac{2(w_{mf} + l_{mf} - 2\delta)}{t_{mf}\delta} \right) \quad (2)$$

with w_{mf} and l_{mf} being metal fill dimensions as shown in Figs. 7 and 8.

In (1), δ is the skin depth and t_{mf} is the thickness of the metal fill. The skin depth is given as,

$$\delta = \frac{1}{\sqrt{\mu\pi\sigma f}} \quad (3)$$

Additionally, L_{mf} and M can be calculated from (4) and (5) as given in [6].

$$L_{mf} = c_1\delta + c_2 \quad (4)$$

where c_1 and c_2 are empirical constants for a metal fill of given dimensions.

$$M = \frac{\mu_0(l_{mf} - \delta)}{2\pi} \log \left(\frac{2b + W_s + 3w_{mf} - \delta}{2b + W_s + w_{mf} + \delta} \right) \quad (5)$$

where b is the distance between the microstrip and metal fill (see Fig. 3). From (1)-(5), we see that the equivalent circuit elements of the metal fill (shown in Fig. 4) depend on metal fill dimensions, its separation from the transmission line and the skin depth (which varies with frequency).

3 METAL DENSITY CONSIDERATIONS

As per the design rules for a given process, there are certain requirements for total metal density. This requirement changes from layer to layer. The typical requirement is 30% to 70% density. The metal fill DRC (design rule check) algorithm calculates the metal density within a moving window of size W_w . The buffer distance can

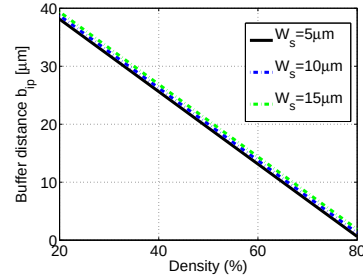


Fig. 5: Buffer distance b_{ip} as a function of required density (D_{req}) for different widths of microstrip; $W_w=100\mu m$, $D_{max}=0.7$.

TABLE 1: Microstrip Designs Under Consideration

Line Width	Height above ground	Line Thickness	Z_0
5μm	9.65μm	2.81μm	90Ω
10μm	9.65μm	2.81μm	85Ω
15μm	9.65μm	2.81μm	65Ω

be increased if metal fill is placed with higher density while satisfying the metal density requirement in a given window. Let D_{req} be the density target for a given layer and D_{max} be the maximum achievable density (metal density requirement upper limit). W_s is the width of the microstrip. The buffer distance for in-plane metal fill can be calculated with (6) and for off-plane metal fill with (7).

$$b_{ip} = \frac{D_{max}(W_w - W_s) - W_w D_{req} + W_s}{2D_{max}} \quad (6)$$

$$b_{op} = \frac{W_w (D_{max} - D_{req})}{2D_{max}} \quad (7)$$

Fig. 5 shows this trade-off for a 0.18μm technology. The maximum possible in-plane buffer distance that can be achieved with 50% density is 20.6μm for a 15μm wide microstrip while the maximum buffer distance is 20μm and 19.3μm for a 10μm wide and a 5μm wide line, respectively.

4 EXPERIMENTAL SETUP AND TRANSMISSION LINE PARAMETER CALCULATIONS

4.1 Setup

We show the impact of metal fill design parameters through full wave simulations [17]. The results are demonstrated for a 0.18μm Bi-CMOS process. The process under consideration has six metal layers M1 through M6. The microstrip under consideration is placed on the top metal layer (M6) with ground plane on M1. All the results are validated for different microstrip designs. Based on the technology stack-up and widths of the line, Table 1 shows the summary of the designs of different microstrip lines used.

Fig. 6 shows two 3D views of the simulation setup. Figs. 7 and 8 show the in-plane and off-plane arrangements of metal fills. w_{mf} and l_{mf} are the metal fill dimensions. A_r is the aspect ratio of width to length.

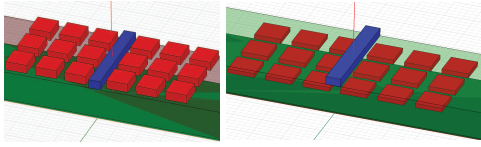


Fig. 6: 3D view of in-plane metal fill setup in HFSS.

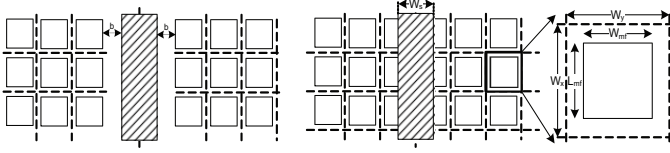


Fig. 7: Top view of the in-plane and off-plane metal fill setup.

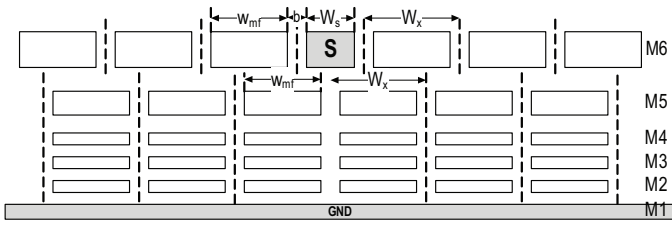


Fig. 8: Stackup of the in-plane and off-plane metal fill setup.

The metal fills are laid out with a unit cell of W_x by W_y calculated from the density requirement, D_{req} , as shown in (8).

$$A_r = \frac{w_{mf}}{l_{mf}} = \frac{W_y}{W_x}; W_x = \frac{l_{mf}}{\sqrt{D_{req}}}; W_y = \frac{w_{mf}}{\sqrt{D_{req}}} \quad (8)$$

The fills are separated from the lines by a buffer distance, b_{ip} , of $2\mu\text{m}$. The inter-layer dielectric thickness between the line (on M6) and off-plane metal fill (on M5) is $2\mu\text{m}$ as well. Fig. 8 shows the cross-sectional view of the setup.

4.2 Calculations

Transmission line characteristic impedance and propagation constant are calculated from simulated full wave S-parameters by converting to ABCD parameters as shown in (9-11). For a lossy transmission line, ABCD (or T) parameters can be written as

$$[T] = \begin{bmatrix} \cosh(\gamma l) & Z_o \sinh(\gamma l) \\ Y_o \sinh(\gamma l) & \cosh(\gamma l) \end{bmatrix}. \quad (9)$$

From these equations, and [S] to [T] conversion tables [18], the characteristic impedance and propagation constant can be calculated via (10) and (11).

$$Z_o = z_p \sqrt{\frac{(1 + S_{11})(1 + S_{22}) - S_{12}S_{21}}{(1 - S_{11})(1 - S_{22}) - S_{12}S_{21}}} \quad (10)$$

$$\gamma = \alpha + j\beta = \frac{1}{l} \cosh^{-1} \left(\frac{(1 + S_{11})(1 - S_{22}) + S_{12}S_{21}}{2S_{21}} \right) \quad (11)$$

In (10), z_p is the port impedance. In (11), α is the attenuation constant and β is the phase constant and l is the length of the transmission line. It will be helpful to compare the normalized phase velocity in each case to demonstrate the slow wave effects due to the metal fill. Therefore, the phase constant, β , can be converted to normalized phase velocity as shown in (12).

$$\bar{v}_p = \frac{\omega}{c\beta} \quad (12)$$

where c is the speed of light in free space. Since the structures under consideration have low loss ($R \ll \omega L$, $G \ll \omega C$), α can be approximated by low the loss approximation [19] as follows:

$$\alpha \approx \frac{1}{2} \left(R \sqrt{\frac{C}{L}} \right) \quad (13)$$

It is straight forward to calculate the *p.u.l.* RLGC parameters from characteristic impedance and propagation constant as shown in (14)-(15).

$$R = \text{Re}(Z_o \gamma); L = \frac{\text{Im}(Z_o \gamma)}{\omega} \quad (14)$$

$$G = \text{Re}\left(\frac{\gamma}{Z_o}\right); C = \frac{\text{Im}(\gamma/Z_o)}{\omega} \quad (15)$$

5 ILLUSTRATION OF IMPACT OF METAL FILL

As discussed in Section 2, the impact of metal fill varies according to different design aspects such as placement, size and shape. This section demonstrates the parasitic impact of the metal fill by varying these design considerations.

5.1 Impact of Placement

As discussed in Section 2, the additional parasitics depend on where metal fill is placed in the E and H fields of the microstrip. Here the impact of metal fills for different layers is studied.

5.1.1 In-Plane (IP) vs. Off-Plane (OP)

Four cases are compared with the no metal fills case: (i) in-plane nominal size ($9\mu\text{m} \times 9\mu\text{m}$), (ii) off-plane nominal size ($9\mu\text{m} \times 9\mu\text{m}$), (iii) in-plane small size ($3\mu\text{m} \times 3\mu\text{m}$), (iv) off-plane small size ($3\mu\text{m} \times 3\mu\text{m}$). In all cases, the metal fill density is kept constant at 50%. Figs. 9-13 show the full wave simulation results obtained with HFSS [17], separated into the capacitive and magnetic parts.

Table 2 summarizes the *p.u.l.* and transmission line parameters for different cases. The off-plane fills have a larger impact on the capacitance. The higher capacitance in the off-plane case can be understood because the fills are placed in a strong parallel field region. The off-plane metal fills are directly underneath the line covering a larger electric flux area as compared to the in-plane fills. The impact on inductance is larger in the case of in-plane fills (see Table 2) and Fig. 10. This is likely because of the larger H field strength normal to the metal fill surface.

TABLE 2: Summary of Impact of Metal Fill on 5 μ m Wide Microstrip Transmission Line at 10GHz

Placement	Area (μm^2)	Shape	R (Ω/mm)	L (nH/mm)	C (fF/mm)	Z ₀ (Ω)	α (dB/mm)	Normalized Velocity ($\bar{v}_p$)
No Fill	-	Square	3.1	0.48	64	87	0.018	0.60
In-plane	81	Square	4.0	0.45	76	78	0.026	0.57
In-plane	9	Square	3.7	0.48	70	83	0.022	0.58
Off-plane	81	Square	3.9	0.47	83	75	0.026	0.54
Off-plane	9	Square	3.6	0.48	77	79	0.023	0.55
In-plane	81	Octagon	3.6	0.47	69	82	0.022	0.59
In-plane	9	Octagon	3.6	0.48	68	84	0.021	0.58
Off-plane	81	Octagon	3.9	0.47	81	76	0.026	0.54
Off-plane	9	Octagon	3.6	0.48	77	79	0.023	0.55
M4 layer	81	Square	3.2	0.48	67	85	0.019	0.59
M4 layer	9	Square	3.1	0.48	66	86	0.018	0.59
M3 layer	81	Square	3.1	0.48	65	86	0.018	0.59
M3 layer	9	Square	3.1	0.48	65	86	0.018	0.59
M2 layer	81	Square	3.1	0.48	65	87	0.018	0.60
M2 layer	9	Square	3.1	0.48	65	87	0.018	0.60
In-plane	81	Plus	3.6	0.47	73	80	0.023	0.57
Off-plane	81	Plus	4.0	0.47	87	74	0.027	0.52

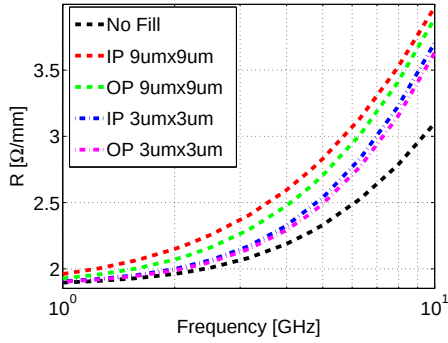
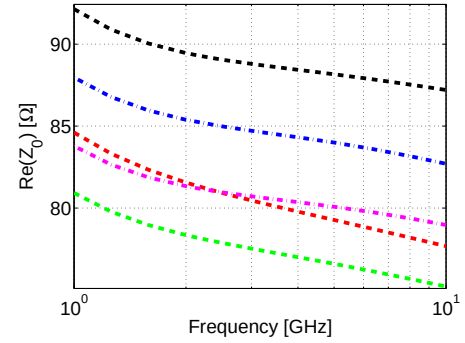
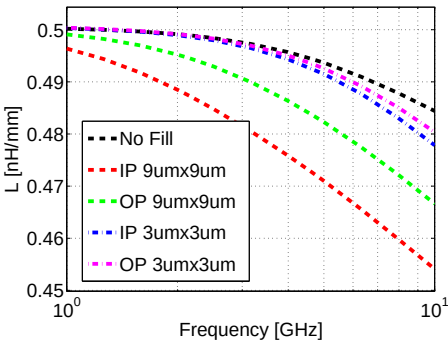
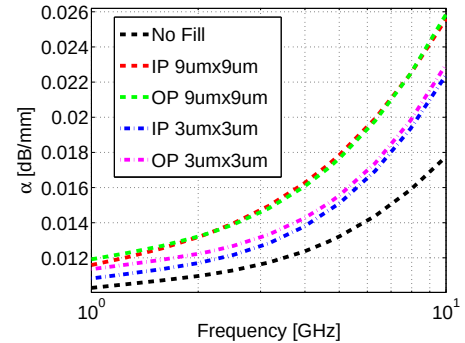
Fig. 9: Impact of metal fill size and placement: *p.u.l.* resistance.

Fig. 11: Impact of metal fill size and placement: characteristic impedance; Legends same as Fig. 9

Fig. 10: Impact of metal fill size and placement: *p.u.l.* inductance.Fig. 12: Impact of metal fill size and placement: *p.u.l.* loss.

The *p.u.l.* resistance shown in Fig. 9 does not show much difference in the two results which can also be seen in Fig. 12. Figs. 11 and 13 show a larger impact of off-plane metal fills on characteristic impedance and normalized phase velocity principally due to dominant capacitive effects.

5.1.2 Various Metal Layers

Apart from these design parameters, the layer or how far the fill is placed in the vertical direction also changes the

impact. When metal fills are placed farther away from the line, the capacitance reduces as the electric fields are spread out approaching the ground plane.

Fig. 16 shows the effect of different metal layers on the characteristic impedance of the transmission line. The fills right underneath the transmission line layer (M5) have the worst impact due to their close vicinity. As expected, when fills are placed on lower layers (M2-M4), the impact reduces. From the electric fields point of view, as the metal fills start moving away from the line,

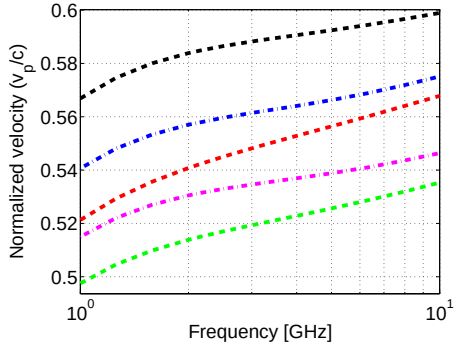


Fig. 13: Impact of metal fill size and placement: normalized phase velocity; Legends same as Fig. 9

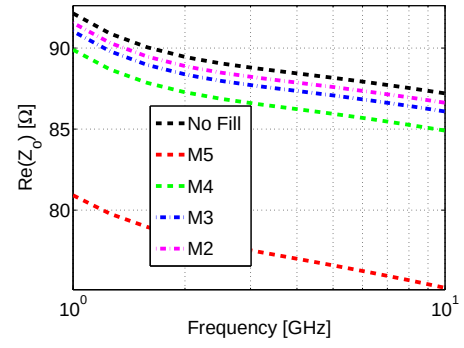


Fig. 16: Impact of metal fill placement on different layers: characteristic impedance.

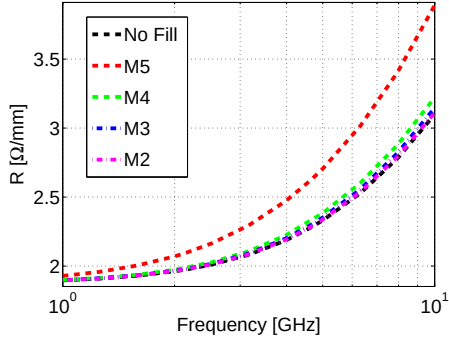


Fig. 14: Impact of metal fill placement on different layers: *p.u.l.* resistance.

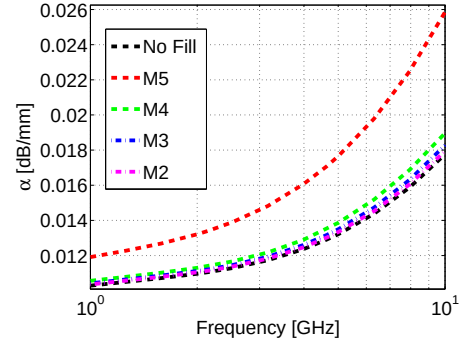


Fig. 17: Impact of metal fill placement on different layers: *p.u.l.* loss.

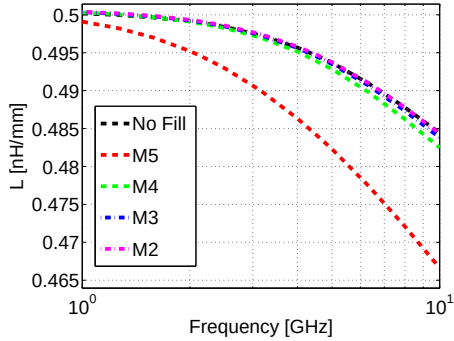


Fig. 15: Impact of metal fill placement on different layers: *p.u.l.* inductance.

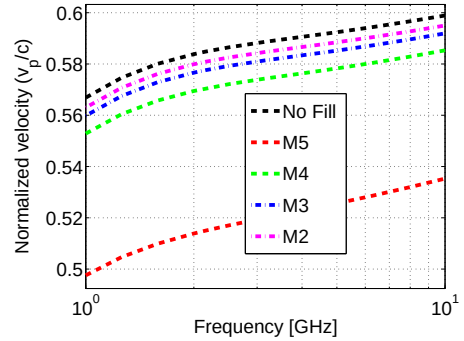


Fig. 18: Impact of metal fill placement on different layers: normalized phase velocity.

the electric field strength reduces and, hence, the total capacitance C_{tot} reduces. This can be illustrated by the results in Table 2 which show the simulated capacitance. When fills are placed at lower metal layers, the magnetic field strength also reduces. This is seen in results for R in Figs. 14 and 17 where the impact reduces moving away from the line.

5.2 Impact of Size

The size of the metal fill also creates a difference in terms of the field interactions. Two metal fill sizes are compared, $9\mu\text{m}$ and $3\mu\text{m}$ side lengths keeping the metal

density at 50%. Table 2 shows the change in capacitance due to different sized metal fills in different layers. For small in-plane metal fills ($3\mu\text{m} \times 3\mu\text{m}$), the capacitance reduces from 76 to 70fF/mm, and from 83 to 77fF/mm for off-plane. As metal fill size is increased, there is a larger amount of metal in the parallel as well as fringing fields, which in turn results in an increase in capacitance. The table also reveals that as metal fills are placed in lower layers, the size difference is less important as the fields are more diffused. The work in [20] has demonstrated an approximate analysis which shows that with smaller metal fill power dissipated in

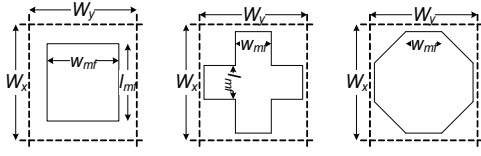


Fig. 19: Metal fill shapes under consideration: square, plus and octagon.

the metal fill is reduced. Figs. 9 and 12 support these findings. It can be seen from Table 2 that the smaller sized metal fill reduces the the resistance from 4 to $3.7\Omega/\text{mm}$ and 3.9 to $3.6\Omega/\text{mm}$ for in-plane and off-plane case, respectively. Thus, in the case of smaller fills, both the eddy current loss and parasitic capacitance are reduced. The characteristic impedance and normalized phase velocity have smaller impact for smaller metal fills as shown in Figs. 11 and 13, respectively.

5.3 Impact of Shape

Most processes use square metal fills in their implementations. Other publications, such as [8], have explored different shapes of metal fill. Along the same lines of improving the electric and magnetic parasitic impact due to metal fill, we have explored two different metal fill shapes: a plus and an octagon. Again, our aim is to reduce the parasitic impact of metal fill for a given metal density and unit cell size. Fig. 19 shows different metal fill shapes under consideration with pertinent dimensions. The cell size $W_x \times W_y$ is kept the same for each shape and accordingly the widths are calculated.

5.3.1 Plus Shape

Fig. 19 shows the plus shape, which is a combination of parallel and lateral lines. The width of this shape is calculated from the cell size W_y assuming an aspect ratio of 1 as in (16).

$$w_{mf,plus} = W_y \sqrt{\frac{D_{req}}{5}} = \frac{w_{mf}}{\sqrt{5}} \quad (16)$$

From Table 2, the plus shape outperforms the traditional square metal fill when placed in-plane (capacitance reduces from 76 to 73 fF/mm, resistance reduces from 4 to $3.6\Omega/\text{mm}$) but worsens the performance when placed off-plane (capacitance increases from 83 to 87 fF/mm, resistance increases from 3.9 to $4\Omega/\text{mm}$). Figs. 21-23 show the performance comparison via transmission line characteristic impedance and propagation constants in an off-plane metal fill case. Thus, the effect of the plus shape depends on the layer in which it is placed. When it is placed in-plane, the metal close to the transmission line is orthogonal to the line and the parallel line is farther away, and hence, an improvement in the performance is seen. When the same metal fill is placed underneath the transmission line, it worsens the fringing fields and, hence, worsens the performance.

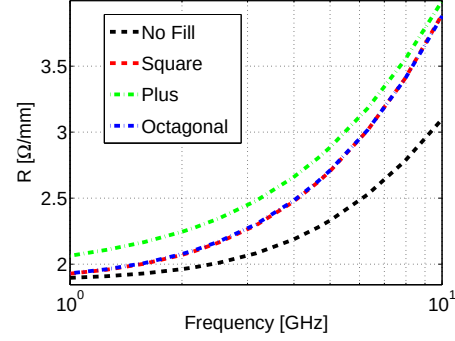


Fig. 20: Impact of off-plane metal fills with different shapes: *p.u.l.* resistance.

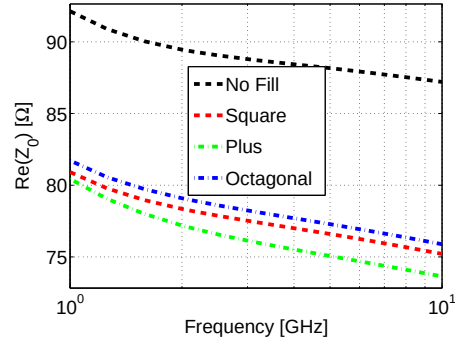


Fig. 21: Impact of off-plane metal fills with different shapes: characteristic impedance.

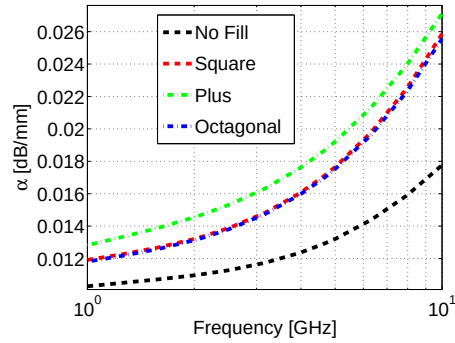


Fig. 22: Impact of off-plane metal fills with different shapes: *p.u.l.* loss.

5.3.2 Octagonal Shape

An octagonal geometry has minimum perimeter for a given area, thus this geometry is of interest. The width of the metal fill in this case can be calculated from the area of a regular octagon (17).

$$w_{mf,oct} = W_y \sqrt{\frac{D_{req}}{2(1+\sqrt{2})}} = \frac{w_{mf}}{\sqrt{2(1+\sqrt{2})}} \quad (17)$$

Referring back to Table 2 and Figs. 20-23, octagonal fills outperform in both in-plane as well as off-plane cases. Their performance is better than the plus shape performance when placed in-plane (capacitance reduces

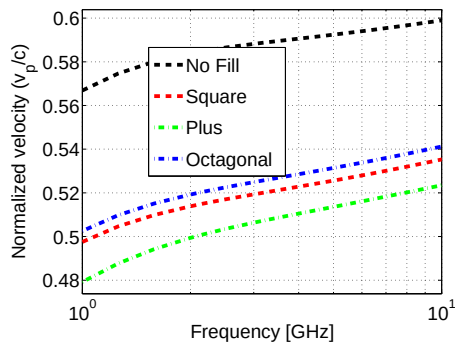


Fig. 23: Impact of off-plane metal fills with different shapes: normalized phase velocity.

from 76 to 69 fF/mm, resistance reduces from 4 to 3.6 Ω /mm). The octagonal metal fill has a smaller amount of metal under the parallel fields and a smaller perimeter, thus the parasitic capacitance due to metal fill reduces. From magnetic field point of view, the induced emf due to time varying magnetic fields reduces for octagonal geometry. Here, also we apply the same principle as in [20] that power loss is proportional to the square of the induced emf and thus the octagonal metal fill improves the *p.u.l.* resistance at higher frequencies as shown in Fig. 20.

6 CONCLUSION AND FUTURE WORK

We have demonstrated the dominant parasitic effects of metal fill on transmission lines. This work has shown the relative impact of different metal fill designs. We used the performance of the microstrip line as criteria for our comparisons. Metal fill placement studies show that in-plane metal fills have a larger magnetic impact when compared to off-plane metal fills but off-plane metal fills have a larger capacitive impact. Lower layers of metal fill give rise to smaller effects when compared to metal fills on the layers close to the line. It can be concluded from this work that for a given metal density requirement, smaller metal fills are generally better. We analyzed different shapes and found that the octagonal shape to be better than the traditional square shape in terms of parasitic capacitance and marginally better in terms of loss performance. However, the off-plane plus shaped metal fill was found to be worse than the traditional square shape, and was better when placed in-plane.

In the future, this work could be extended to coupled lines. Designs actively utilizing metal fill could be explored, for example, using metal fill in a slow wave structure and using patterned grounded metal fills as a means of dispersion reduction in on-chip interconnects.

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