NEXT Reduction In Package Interconnects

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***Abstract*—In high speed, high density packages, Near End Cross Talk (NEXT) is one of the parameters that determines the maximum reach attainable. This paper presents a new differential interconnect which consists of a hybrid combination of broadside and edge coupled differential geometries. P and N traces are routed as complimentary twisted pairs. Numerical results show that a substantial reduction in NEXT levels is feasible.**

***Keywords*— Package interconnects, NEXT, FEXT.**

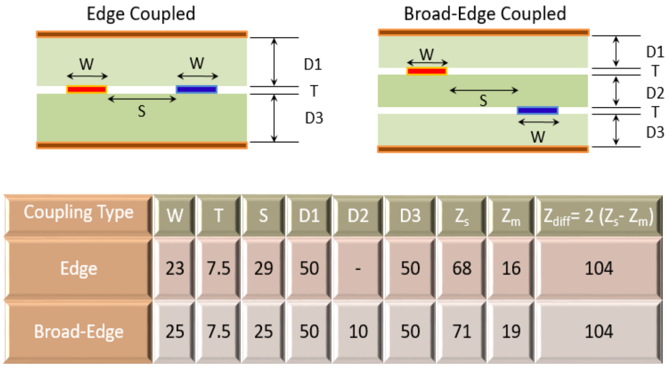
I. INTRODUCTION

Long Reach Electrical Interfaces operating at 112G PAM4 data rates and beyond need to be designed to meet stringent requirements on the insertion loss, return loss and crosstalk [1-2]. State of the art active devices can overcome large values of insertion loss in the link. However, it is the crosstalk level that limits the maximum length of the link. This leads to limits on the Insertion Loss to Cross talk Ratio (ICR), Integrated Crosstalk Noise (ICN), or more realistically COM (Channel Operating Margin). Crosstalk is conveniently defined at the near end or the far end.

NEXT is usually the dominant one as compared to FEXT (Far End Cross Talk) and it is it's value on the package very close to the die that is important. Most high-speed and high-density packages prefer use of Flip-chip technology [3] and buried (stripline) routing. Interconnect cross talk levels are generally reduced by increasing spacing and using grounded guard traces. Where the differential pair density is high, closely spaced, and necked interconnect routing over extremely short distances near the flip chip balls becomes inevitable and this leads to increased NEXT [4]. This paper presents a new interconnect that can result in a substantial reduction of NEXT.

II. DESCRIPTION OF INTERCONNECT

Uniform edge coupled differential transmission lines are the most commonly used forms of interconnect. Further, buried/internal/stripline routing reduces radiation and cross talk. Broadside coupled differential pair geometries are known to require thicker substrates. The edge-coupled differential pair has a primary advantage that it can be implemented with a reduced PCB thickness and layer count. The broadside coupled trace geometry can be modified by offsetting the two traces leading to a "Broad-Edge" Coupled configuration (Fig.1). This reduces the coupling between traces and the layer thickness required for a given impedance. While there is no apparent advantage in this configuration, it helps in the construction of a pseudo- twisted pair as shown in Fig.2.



Coupling Type	W	T	S	D1	D2	D3	Z_s	Z_m	$Z_{diff}= 2 (Z_s - Z_m)$
Edge	23	7.5	29	50	-	50	68	16	104
Broad-Edge	25	7.5	25	50	10	50	71	19	104

Fig. 1. Cross sectional view of Differential transmission line geometries (Dimensions in microns, Substrate ABF GZ41)

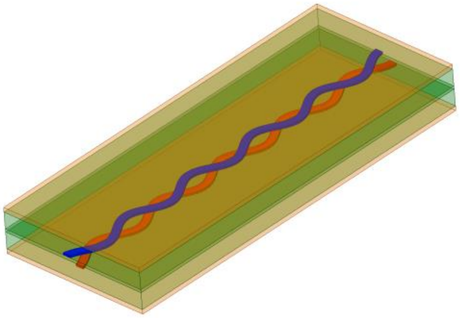


Fig. 2. Illustration of non-uniform interconnect

III. NUMERICAL RESULTS

First, to obtain a reference, a 2000 um long edge coupled stripline of Fig. 1 is simulated.

The P-trace of the non-uniform diff pair of Fig. 2 is constructed by sweeping the rectangular trace cross section (W x T) along a path defined by

$$x(t) = t,\ y(t) = \left(\frac{S+W}{2}\right) Cos\left(\frac{\pi t}{T}\right),0 \le t \le 2000\ um \qquad (1)$$

The N-Trace is obtained by multiplying y(t) with -1. Due to the overlapping regions, this geometry has more capacitance and its characteristic impedance is less than that of the uniform line of Fig.1. This is compensated by reducing the trace width to 18 um and increasing the gap to 29 um. For a fair comparison, the end-to-end distance of both cases is fixed at 75um.

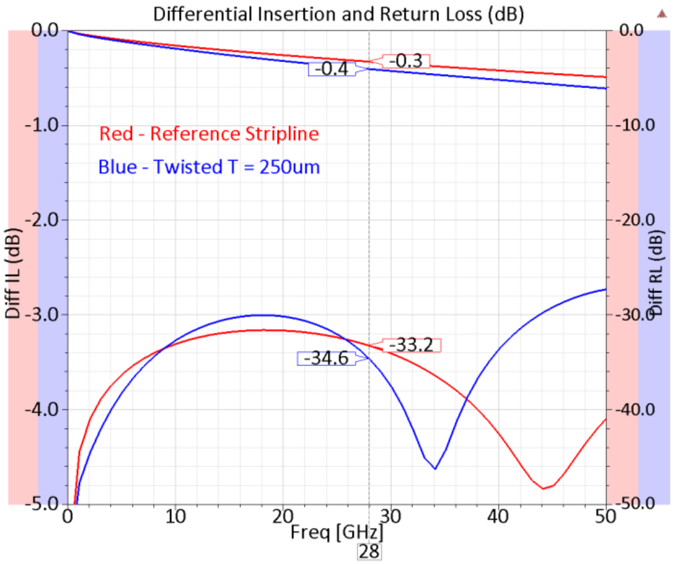


Fig. 3. Computed s-parameters of a single pair

Computed results are shown in Fig.3. It can be seen that the twisted pair will have an increased insertion loss arising from the longer path length and the narrower trace.

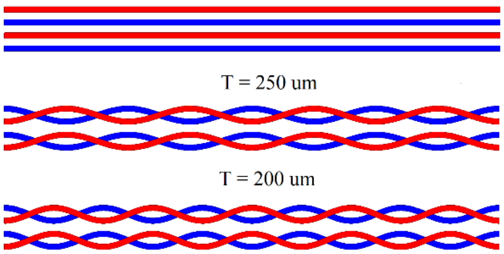


Fig. 4. Illustration of the top view of the 3 cases considered

To compare crosstalk levels, a pair of traces placed side by side with a spacing of 30um as shown in Fig. 4 is simulated. The straight stripline case has the same cross section as in Fig 1. In the case of twisted pair cables used to carry Ethernet data, it is known that the performance depends on the number of twists per unit length. For this reason, two different twist periodicities are considered. In the simulations, the end to end distance in the cross section is maintained at 180um in all cases.

Computed s-parameters show differential insertion and return loss values very close to that in Fig. 3. Fig. 5 shows a comparison of the NEXT values and it can be seen that a reduction of 9dB is feasible with value of T = 250 um which amounts to 8 twists over the length. Increasing the number of twists to 10 along the length only results in a small improvement in the NEXT Level.

The transmission line structure is non-uniform and its characteristics cannot be easily extrapolated. For example, the structure has odd mode and even mode velocities that are different. To obtain a better understanding of its behavior, computed results of near fields of a single pair of the 3 geometries of Fig. 4 are shown in Fig. 6. The computation of the total electric field is carried out on plane surface at a height of 15 um from the top trace at a frequency of 25 GHz. The left end is differentially excited with 1V source and the right end is terminated in a 50 Ohms load. Both non-uniform geometries show a field intensity that decreases rapidly away from the traces and contain a multitude of local minima that contribute to field strength reduction. While a reduction in NEXT is evident, it is also important to ensure that other characteristics are not compromised. A comptation of the FEXT level is carried out and the result is shown in Fig. 7.

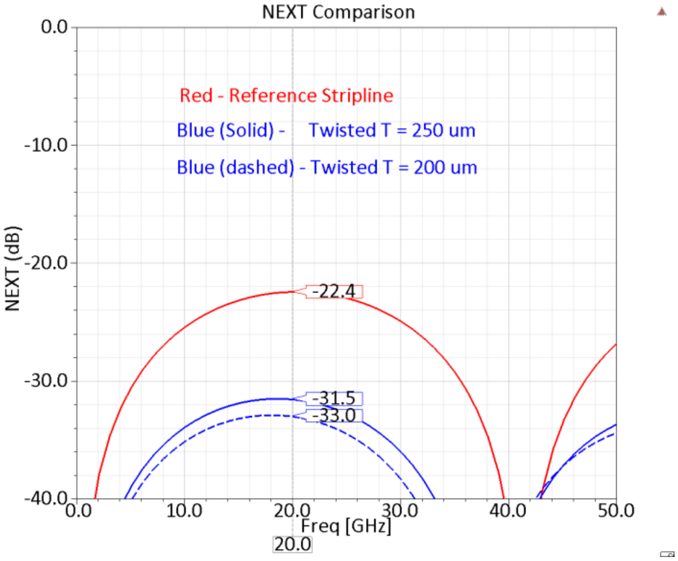


Fig. 5. Computed NEXT levels for the 3 cases in Fig. 4

While FEXT shows some reduction at low frequencies for T = 250 um, it remains nearly the same as the stripline at high frequencies. Increasing the number of twists leads to an improvement in the NEXT level. However, it can increase the FEXT level substantially. This is also evident from the near field distribution which shows a higher field strength for T= 200 um in the region that contributes to FEXT.

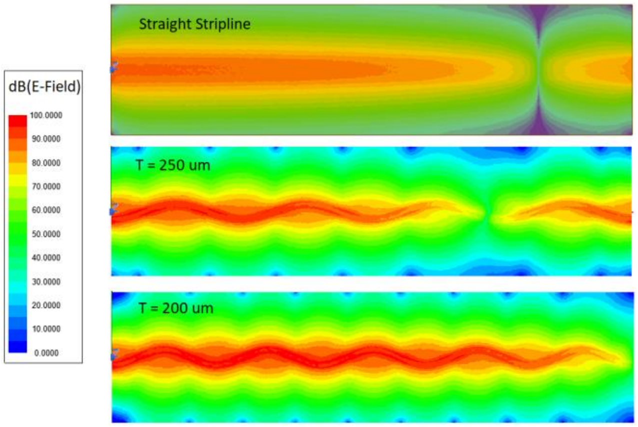


Fig. 6. Near Electric field distribution of a single pair at 25 GHz

To further asess the full impact of both types of cross talk, an example of 7 parallel pairs with an inter-pair spacing of 30 microns is considered. The middle pair is treated as victim and the total power sum of NEXT and FEXT levels termed PSXT is shown in Fig. 8. A 10 dB improvement is seen in both cases.

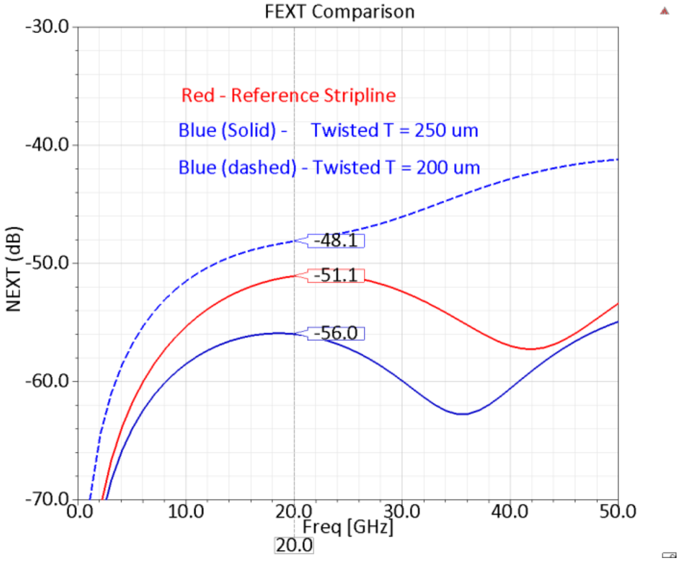


Fig. 7. Computed FEXT levels for the 3 cases in Fig. 4

IV. CONCLUSION

In this work, a new transmission line structure is proposed for the reduction of NEXT levels in package interconnects. The configuration is non-uniform and has characteristics that exhibit strong frequency dependence. By a careful combination of dielectric thickness, width and periodicity, it is possible to obtain a substantial improvement in cross talk levels without compromising other parameters significantly. An optimum value of twist periodicity exists. There are also other benefits in printed circuit board applications [5]. A main drawback seen is the need for an additional routing layer. In a real application, this can result in twice the number of routing layers needed. However, since the additional substrate layers are very thin, the overall increase in package thickness will be less than twice the nominal thickness using straight edge coupled striplines.

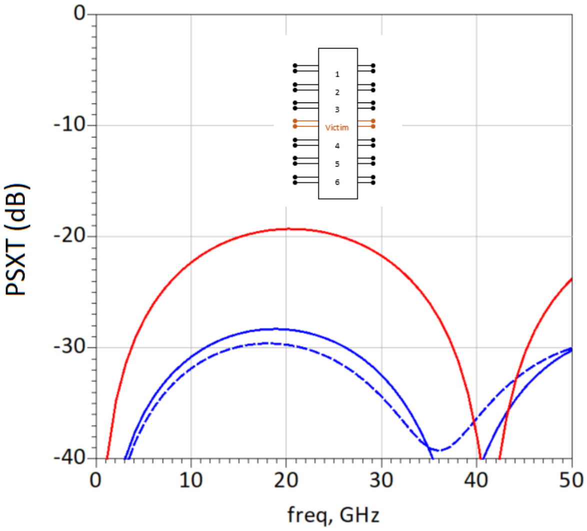


Fig. 8. Computed PSXT levels for the 3 cases in Fig. 4

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