An Original Modeling Process and Technology with Intra-Package Crosstalk Consideration for Compact Array Antennas on the 4G Communications Packages

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Abstract

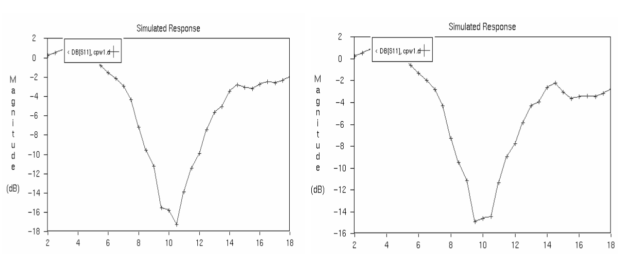
The affect of electromagnetic interference arising from different layers, structures, and properties of smart antenna array elements on 4G systems is presented. Novel modeling issues resulted from the analysis shows possibility to reduce package size, introduce new package architecture, and improve the performance of the package.

1. Introduction

The 4G systems with adaptive antenna arrays will be providing multiple wireless services to the users [1]. Typically, each antenna is placed $\lambda/2$ apart from the others to avoid crosstalk [2]. This introduces a packaging problem due to size restrictions [3]. However, even this spacing doesn't eliminate the electromagnetic interference and as the number of elements increases, the effect on the performance of the array as well as the surrounding co-package components increases [4]. For the first time, we provided a package-based solution from strategically testing and modeling the effect of the patch, the frequency, and the substrate. The results implement a way to reduce the size of the antenna array and the packaging of the array and other systems together considering the electromagnetic crosstalk effect.

2. Experimental Setup

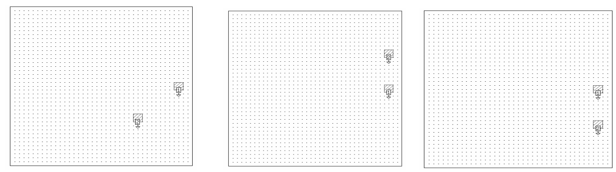
First, we designed a microstrip patch antenna on a large substrate that operates around 10.5 GHz. Its return loss and the result from the minimum separation necessary test to avoid crosstalk with the other systems on the package is shown in Fig. 1. The minimum separation is found to be $\lambda/10$. We prepared two testbeds to experiment on all the scenarios. The first testbed is with two elements at various orientations and distances and is shown in Fig. 2.



(a) (b)

Fig. 1. (a) The return loss of the designed antenna, and (b) the crosstalk at 100 mil separation for a 200 mil-200 mil microstrip element and other systems on the package

The other testbed is made up with multiple antennas surrounding a particular antenna under test for crosstalk.



(a) (b) (c)

Fig. 2. Testbed with two antenna elements arranged 700 mils apart (a) diagonally, (b) vertically with test antenna feed pointing toward the other, and (c) vertically with test antenna feed pointing away from the other

This is shown in Fig. 3.

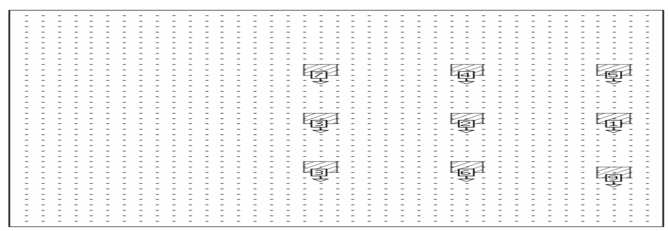
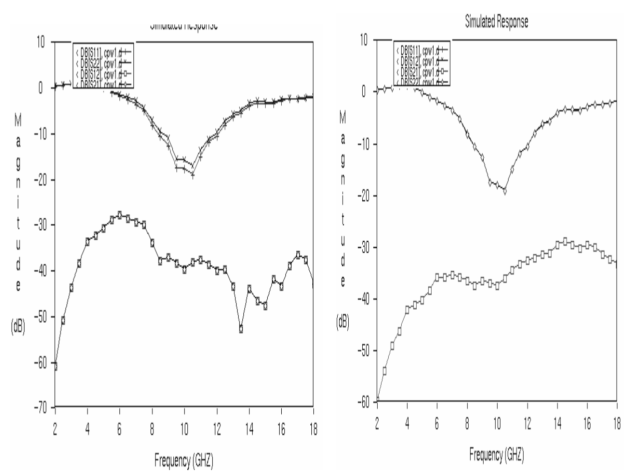


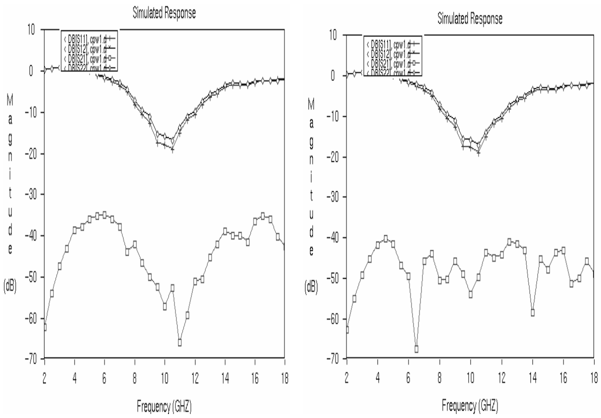
Fig. 3. Testbed with multiple antenna elements

3. Experimentation with Two and Multiple Designed Antennas at the Same Frequency

Except for the vertical case, the rest shows the return loss (top curves) to be affected by each other. In Fig. 4c, the diagonal placement shows a significant reduction



(a) (b)



(c) (d)

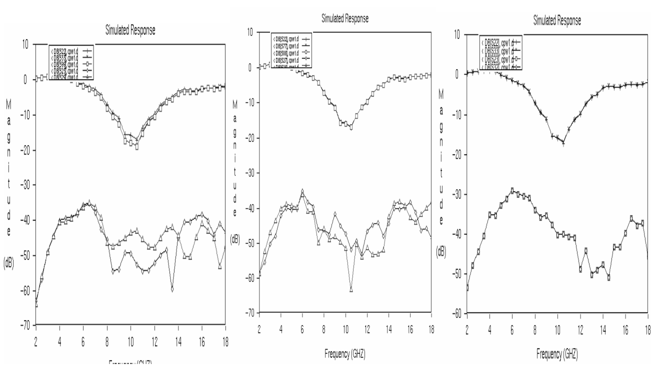
Fig. 4. Return losses and crosstalks for two elements placed (a) horizontally 700 mils apart, (b) vertically (for both orientation of the feed) 700 mils apart, (c) diagonally 700 mils apart, and (d) horizontally 1400 mils apart

in crosstalk (bottom curves). This is due to the directive radiation.

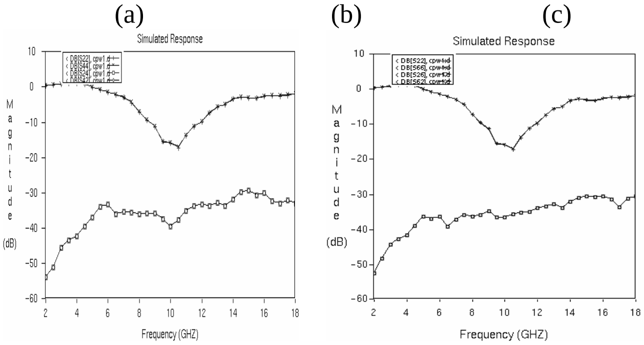
In Fig. 5a, the upper element, having less surrounding elements than the lower shows lesser crosstalk. The lower left corner element in Fig. 5b, being the farthest from the other components and diagonally positioned, is least affecting the overall intra-package radiation.

In Fig. 5c, the horizontal element gets influenced and coincides with the center elements radiation pattern. However, other elements interactions significantly reduce the isolation than could be predicted using Fig. 4a.

From Fig. 5d and Fig. 5e, it is observed that the bottom element is more isolated near resonance. Also, the two vertical cases are different now as oppose to Fig. 4b.



(a) (b) (c)

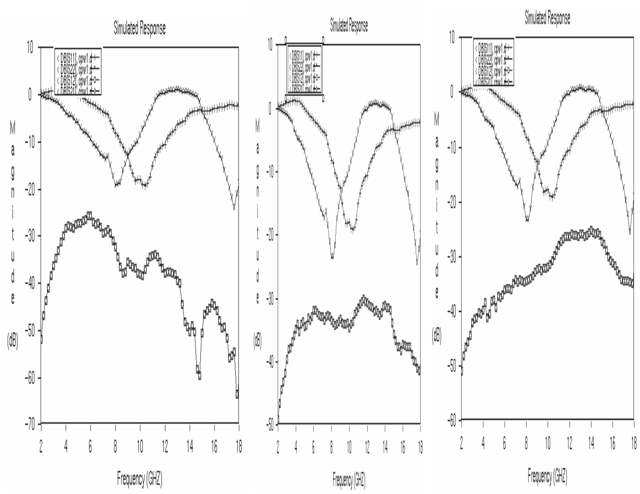


(d) (e)

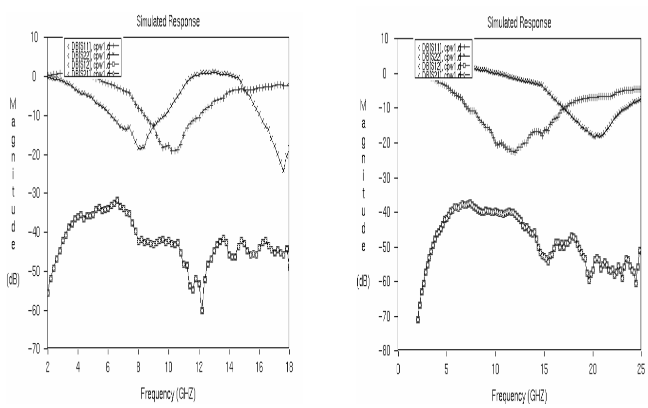
Fig. 5. Multiple elements case with the central and elements in (a) upper and lower right, (b) upper and lower left, (c) horizontally left, (d) upper, and (e) bottom

4. Experimentation with Two and Multiple Designed Antennas at Different Frequencies

For multi-frequency elements, as shown in Fig. 6, the crosstalk level is ~10 dB higher or lower than the previous case for coupling with a double or half size antenna, respectively. The difference in return loss affects the crosstalk as is evident from these results. Being different from the case in Fig. 4b, Fig. 6b and Fig. 6c recommend vertical placement for better isolation. Crosstalk is less improved for the placement of a higher frequency patch vertically at the bottom than the top. Fig. 6d-e, similar to Fig. 4c, shows improvement in crasstalk isolation for diagonal separation although the feat was less than before.



(a) (b) (c)

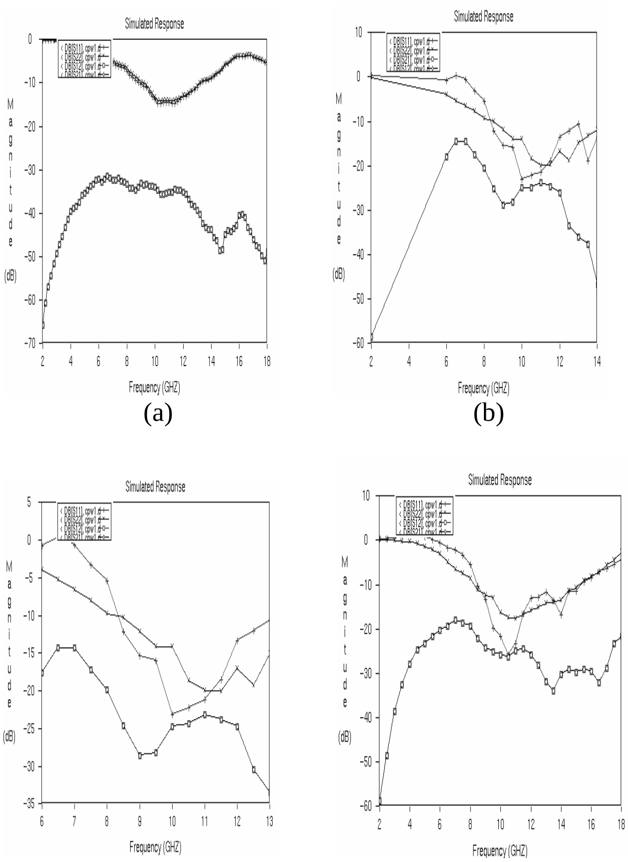


(d) (e)

Fig. 6. Crosstalks for the 10.5 GHz antenna placed (a) with a lower frequency patch horizontally 700 mils apart, (b) with a lower frequency patch vertically on the top 700 mils apart, (c) with a lower frequency patch vertically on the bottom 700 mils apart, (d) with a lower frequency patch diagonally 700 mils apart, and (e) with a higher frequency patch horizontally 700 mils apart for comparison

5. Substrate Layer Effects

Decreasing the substrate dielectric constant by 60% and increasing its loss tangent by 300% shows a significant increase in crosstalk level of ~10 dB at the resonance as depicted in Fig. 7a. From Fig. 7b, it is evident that various dielectric layer heights for individual elements also have effect on the crosstalk performance. Comparing Fig. 7b with Fig. 7c, dielectric embedding with various heights seems to be a feasible technique to reduce crosstalk. Fig. 7d shows the case where only major interfaces



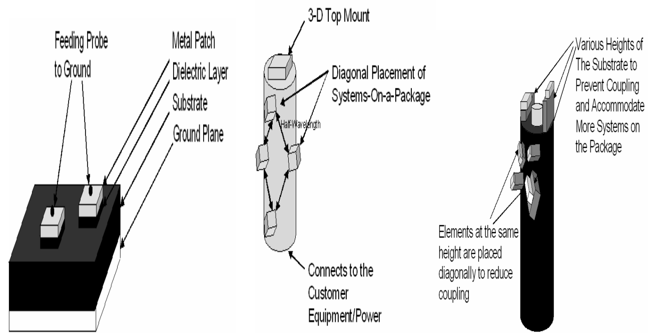
(a) (b) (c) (d)

Fig. 7. Crosstalk and radiation for dielectric layer variation with (a) various dielectric constants and loss tangents, (b) various heights, (c) various heights and embedded patch, and (d) only major interfaces between the patches surrounded

of the radiating patch were sealed with dielectrics rather than a more expensive embedding of the whole patch. It shows similar performance and could be a useful extension to the embedding notion.

6. Package Design

The 2-element array system is shown in Fig. 8a. Using our analysis on postioning and crosstalk, we have designed a conformal 3-D package structure where elements are placed only diagonally half the wavelength or vertically one wavelength apart for proper functioning of the package by reducing the heavy crosstalk noise. Also, using the dielectric layer analysis, we placed the system with the highest power mounted on the top. The feed goes across the center of the conformal substrate body. Fig. 8b shows these design aspects. In Fig. 8c, further enrichment of the design is done by placing components with various heights in their dielectric layers. This enables the packaging of a lot more components with the same signal-to-noise ratio (SNR) due to the horizontal placement and less than half-wavelength separation possibility of the systems.



(a) (b) (c)

Fig. 8. (a) The 3-D view of an array, (b) diagonal and conformal architecture of the array and other package components for interference reduction, and (c) the final designed package with dielectric layer variation and the diagonal-conformal structure

Moreover, semi-dielectric-embedding (SDE) and blocking is applied to further reduce crosstalk among the elements economically. Thus our packaging allows for a compact, cheap, and high performance technology.

7. Conclusions

We performed design and simulations on two and multi-element antenna arrays operating at a single or multiple frequencies. We analyzed and recorded the crosstalk reading for element position and dielectric layer dimension and parameter variation. The findings lead to a novel packaging technology that uses the diagonal and vertical positioning advantage among the elements at the same heights due to the radiation directivity, and different dielectric layer height and parameter with SDE and major interference direction blocking for inexpensively package more components with the benefit of component distance reduction and horizontal assignment with no performance degradation.

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