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Crosstalk Reduction Technique For GPS Transmission Lines in 5G Smartphones

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Abstract *- Navigation and positioning systems are very crucial now due to their extensive applications. Radiofrequency interference (RFI) can occur in a phone due to the closeness of the band spectrum emitted from the phone components and the weak isolation due to phone size limitations or miniaturization. Among the other sources, crosstalk noise is a major factor for RFI. Crosstalk noise is a major threat to electromagnetic compatibility (EMC) and Signal Integrity (SI).In this study, a new design for serpentine guard trace (SGT) in the presence and absence of vias is proposed to reduce the crosstalk effect in Global Positioning System (GPS) in 5G smartphones. Then, the Near-End and Far-End Crosstalk (NEXT and FEXT) for the proposed design in the frequency range of GPS of 1.1 to 1.5 GHz was studied. The NEXT (S31) and FEXT (S41) were calculated using Computer Simulation Technology (CST) microwave studio software. Also, the parameters that affect the Crosstalk reduction were optimized using Response Surface Methodology (RSM). The results show that the values of NEXT and FEXT vary with frequency, horizontal segment width, and the number of vias. The highest reduction of NEXT and FEXT were achieved when Serpentine Guard Trace Vias (SGTV) with 0.9mm width was used. By using Serpentine Guard Trace (SGT) instead of rectangular Guard Trace (GT), the NEXT values were reduced by around 25dB. Also when vias were added, the NEXT values were reduced by around 33.8 dB. While the FEXT values were reduced by around 11 dB with no vias and around 23dB in the presence of vias. For the electric field distribution, using a serpentine guard trace reduces the intensity of the electric field. Also, by adding vias, the attenuation of the electric field increases suggesting a reduction in crosstalk. For magnetic field distribution, using a serpentine guard trace reduces the intensity of the magnetic field. Also, by adding vias, the attenuation of the magnetic field increases, and this suggests that there is a reduction in the induction effects acting on the victim line that leads to a reduction in the crosstalk.*

I. INTRODUCTION

Recently, navigation and positioning systems have become very significant due to their use in many applications, including smartphone navigation systems. Global Positioning System (GPS) conveys data at L1 and L2, which correspond to frequencies of 1575.42MHz and 1227.60 MHz, correspondingly[1, 2].

The GPS receiver's positioning accuracy can be affected by many possible errors from different sources. Recently, the 5G technology is mostly utilized for transmitting and receiving information through wireless communication systems, especially via mobile phones. These technologies affect GPS services due to free space and spectral interference. Within mobile phones, the 5G services are operated at such proximity to the GPS receiver frequency[3].

The GPS receiver's positioning accuracy can be affected by many possible errors from different sources. A change in travel time or signal attenuation of the GPS satellite can be caused by several natural or unnatural phenomena. Receiver noise can be due to thermal, distortion, and other noise sources within the receiver itself [3].

The 5G transmitter's operations at frequency bands (low band (below 3 GHz), the middle band (3-6 GHz), and the high band (mainly above 24GHz). Also, RF interference happens in the phone because of the closeness of the band spectrum emitted from the phone elements and the weak isolation due to phone size limitation[4, 5].

RFI from various sources could be in the form of conducted or radiated. These RFI can lead to undesired outcomes such as signal failure at the transceiver within the mobile phone where Crosstalk noise is the major factor for EM interference among the other sources. Crosstalk has gained huge attention due to the design compactness between smartphone components and their connections. This problem arises because of the closeness of the lines and can be deemed as the main source of noise in PCBs. This can be alleviated by some design practices[6].

One of the widely proffered solutions to minimize the crosstalk noise is increasing the distance between the striplines, which has the effect of reducing the capacitive and inductive coupling coefficients. However, this often leads to a significant increase in the size of the PCB. Another solution is to practice the use of guard traces and vias. Still, different guard shapes such as rectangular and serpentine guard traces have been used, but the crosstalk noise is still very high[7-15].

In [16] study, a novel U-shaped guard shield was used to reduce near-end and far-end crosstalk. Ansoft HFSS simulation was used to calculate crosstalk noise. The width (w) of the trace was 2mm, and the spacing (s) between two conducting traces was 2w (4mm), and the length (L) of the trace is 50mm. The vertical and horizontal guard segments were chosen to be 10mm and 6mm, respectively. The simulation was studied in the frequency range of 0-6 GHz, and results show that NEXT and FEXT were reduced by 20 dB and 15 dB using a U-shaped guard trace.

In this study, a new design for serpentine guard trace in the presence and absence of vias is proposed. Then, the Near-End and Far-End Crosstalk (NEXT and FEXT) for the proposed design in the frequency range of 1.1 to 1.5 GHz was studied. The NEXT (S_{31}) and FEXT (S_{41}) were calculated using CST. Also, the parameters that affect the Crosstalk reduction were optimized using (RSM).

II. Methodology

The proposed designs and analysis were done using CST microwave studio software. The designs are classified into two main categories: GT and SGT in the presence and absence of with vias. The crosstalk for each design was generated between the two traces in terms of NEXTand FEXT, where each model consists of a four-port network, as shown in figure 1. The scattering parameter of NEXT was expressed with the S_{31} symbol, and the scattering parameter for FEXT was expressed with S_{41}symbol.

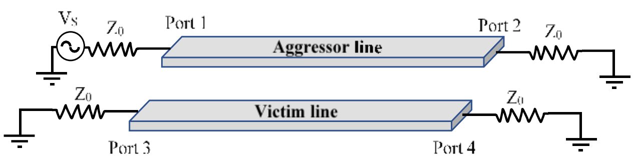

Figure1: Modeling set-up of the striplines

For all cases, the signal was injected to the aggressor line terminal from port 1 using the radio frequency (RF) source with operating frequencies (1.1-1.5 GHz) and internal impedance of 50 Ohms. The remaining three ports were terminated with 50 Ohms. The striplines were placed on the Printed Circuit Board (PCB). The striplines were placed on the Printed Circuit Board (PCB), where the substrate dielectric constant is 4.3 (FR_4 material) with 2.0 mm width and 1.6 mm thickness. The traces were made from copper with 0.3 mm width and 0.035 mm thickness. The spacing between the two traces was equal to 3w (0.9 mm). The copper ground has covered the substrate from behind with 0.035 mm thickness.

A. Guard trace in between two traces in the presence and absence of vias

Four guard trace configurations were investigated to study the crosstalk behavior. Figure 2. show the proposed designs (a) Guard trace (GT), (b) Guard trace vias(GTV), (c) Serpentine guard trace (SGT), and (d) Serpentine guard trace vias(SGTV).

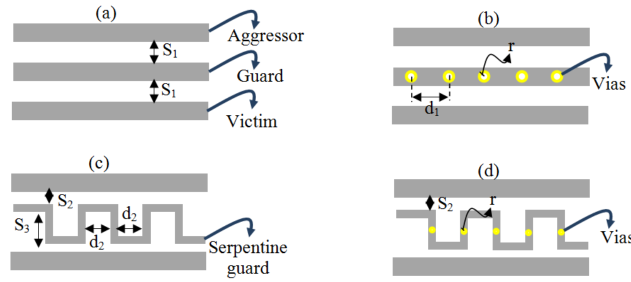

Figure2:Proposed designs (a) GT, (b) GTV, (c) SGT, and (d) SGTV.

The physical dimensions of the guard traces designs mentioned inFigure 2. were considered for the numerical simulations. The simulation parameters for the guard traces and their variations are given in table1.

Table1:The dimensions of the guard striplines

Symbol	S_1	S_2	S_3	d_1	d_2	r
Value(mm)	0.3	0.1	0.5	0.8-8.4	0.2-2.6	0.4

II. RESULTS AND DISCUSSIONS

A. Simulation results

This section presents and discusses the simulation results of the crosstalk reduction for the proposed PCB microstrip structures. CST microwave software was used to simulate the proposed designs of the microstrips.

The simulated curves of the NEXT are plotted and presented in figure 3. The simulated results show that the highest reduction of NEXT was achieved with SGTV followed by SGT, GTV, GT, and no guard, respectively, in the frequency range of 1 to 1.5 GHz.

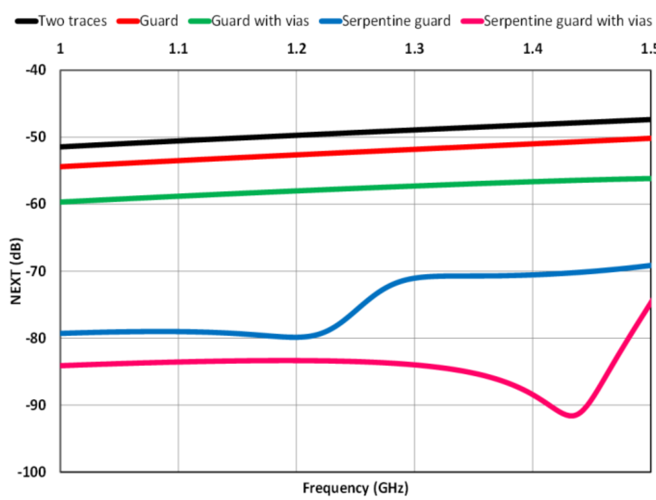

Figure3: NEXT curves of the guard trace in the presence and absence of vias.

The simulated curves of the FEXT in the frequency range of 1 to 1.5 GHz are plotted in**Error! Reference source not found.** figure 4. The simulated results show that the highest reduction of FEXT was achieved with SGTV followed by SGT, GTV, and finally no guard and GT, correspondingly.

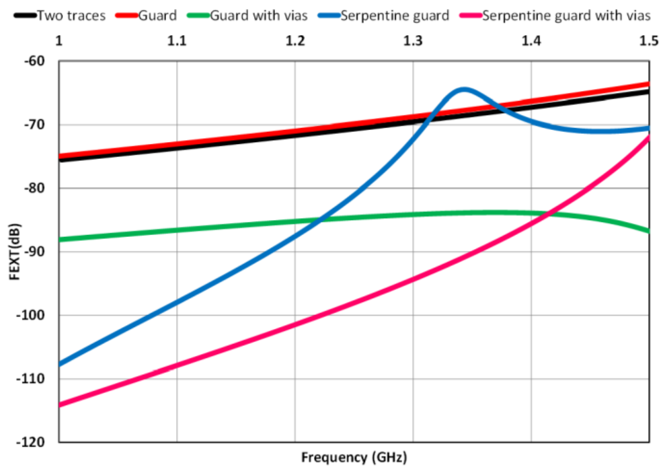

Figure4: FEXT curves of the guard trace in the presence and absence of vias.

The simulated results of the NEXT are presented inTable2. The results show that the values vary with frequency and the types of the guard. The highest reduction of NEXT was achieved when SGTV was used. The NEXT values difference and the percentage difference between the SGTV and the no guard were in the ranges of 27 to 40 dB and 44% to 59%, respectively. While the lowest reduction ofNEXT was achieved with GT. The NEXT values difference and the percentage difference between the GT and no guard were in the ranges of 2.7to2.9 dB and 5% to 6%, respectively.

Table2:NEXT results of the guard trace in the presence and absence of vias.

Guard type	Frequency (GHz)				
	1.1	1.2	1.3	1.4	1.5
No guard	-50.54	-49.71	-48.92	-48.13	-47.40
GT	-53.47	-52.63	-51.83	-51.00	-50.15
GTV	-58.82	-58.01	-57.31	-56.65	-56.17
SGT	-79.02	-79.86	-71.06	-70.56	-69.14
SGTV	-83.54	-83.38	-83.96	-88.26	-74.70

The simulated results of the FEXT are presented in Table 3. The results show that the values vary with frequency and the types of the guard. The highest reduction of FEXT was achieved when SGTV was used. The FEXT values difference and the percentage difference between the SGTV and the no guard were in the ranges of 7 to 34 dB and 44% to 59%, respectively. At the same time, the lowest reduction of NEXT was achieved with GT. The FEXT values difference and the percentage difference between the GT and no guard were in the ranges of 0.5 to 1.2 dB and 0.8% to 2%, respectively. Using guard trace vias reduces capacitive mutual (Cm) and inductive mutual (Lm) together and can therefore simultaneously reduce NEXT and FEXT[17, 18].

In the [7], SGTV was used to study the crosstalk reduction, where Ansoft HFSS software was used to simulated the *S*-parameters for the FEXT and NEXT crosstalk. The frequency range was 0-6 GHz, and the parameters were: $\varepsilon r \approx 4.5$, w = 3mm, and s = 8mm. The simulated results show that SGTV enhanced the NEXT by 7.65dB comparing with no guard. While the FEXT was reduced by 7.22 dB comparing with no guard. However, the results proposed in our model in this paper show higher improvement in crosstalk reduction than in [7], with differences about 26.12 dB and 15.76 dB for NEXT and FEXT, respectively.

Table3:FEXT results of the guard trace in the presence and absence of vias.

Guard type	Frequency (GHz)				
	1.1	1.2	1.3	1.4	1.5
No guard	-73.67	-71.69	-69.58	-67.25	-64.83
GT	-73.08	-71.02	-68.80	-66.39	-63.59
GTV	-86.62	-85.25	-84.14	-83.88	-86.73
SGT	-98.16	-87.90	-72.50	-69.37	-70.51
SGTV	-108.0	-101.6	-94.42	-85.76	-72.04

The electric field distribution plotted using CST Microwave Studio is shown in Figure 5. The figure presents the results for the excitation of port 1 with an EM source to investigate the electric field distribution on the PCB micro strip line. From the figure, using a guard reduces the electric field that propagates. This suggests that most of the electric field has been attenuated. It was observed that using serpentine guard trace reduces the electric field intensity significantly than the conventional guard trace, as shown by differences in the intensity of the electric field spectrum. By adding vias, the attenuation of the electric field increases suggesting a reduction in the intensity of the electric field, which decreases the capacitive coupling between the victim and aggressor lines, which in turn reduces crosstalk in the victim line.

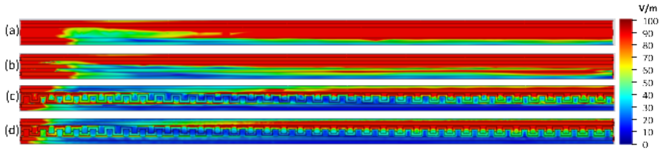

Figure5: Electric field contour distribution on the surface of (a) two traces (b) Guard trace, (c) Serpentine guard trace, and (d) Serpentine guard trace vias at 1.1 GHz.

The magnetic field distributions are plotted and shown in Figure 6. The figure presents the results for the excitation of port 1 with an EM source to investigate the magnetic field distribution on the PCB microstrip line. From figure6, using a guard reduces the magnetic field that propagates; this suggests that most of the magnetic field has been attenuated. It was observed that using serpentine guard trace also has reduced the magnetic field intensity than the conventional guard trace, as shown by differences in the intensity of the magnetic field spectrum; with adding vias, the attenuation of the magnetic field increases. This suggests that less induction affects the victim line, which led to a reduction in the crosstalk value. The results show good agreement with the measured NEXT and FEXT values.

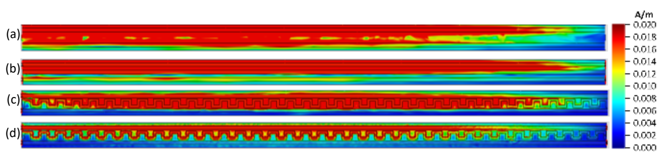

Figure6: Magnetic field contour distribution on the surface of (a) Two traces, (b) Guard trace, (c) Serpentine guard trace, and (d) Serpentine guard trace vias at 1.1 GHz.

B. Simulation design and optimization

Response Surface Methodology (RSM) from Design Expert software was used to design the simulation. The design was built to study the relationship between the input variables (frequency, number of vias, and horizontal length of serpentine (w)) and the response (NEXT and FEXT). In addition, it helped to determine the values of the optimum variables that contribute to getting the highest (optimum) response.

To evaluate all designs, data analysis, and diagnostic tools available in the software module, specifically: analysis of variance (ANOVA) tables and diagnostic plots. These tools were used to validate the design. ANOVA as a hypothesis testing process was employed to test if the variables mean are meaningfully affecting the response value. F-values were evaluated to determine the size of the effects by comparing the ratio of the differences between the mean variables. It was realized that the change in F-value has an impact on the variables. A large value of F suggests that the variable has a real and large effect on the value of the response in the model. If the F-value ratio in the model shows no significant impact, this means that the model has no effects, and the hypothesis can thus be rejected.

The optimization was done for the variables, and the response was optimized by specifying the goals for each one. It was chosen in range for all the variables and minimize for all the responses. Then a list of the optimum possible solutions was generated from the software to get the optimum output (response) for each design.

C. Design evaluation and diagnostic

The design was evaluated using the Analysis of Variance (ANOVA) table (which is a collection of statistical models and their associated estimation procedures used to analyze the differences among means) and some diagnostic plots. This was done to test if the mean of the three variables is significantly affecting the response value. Table 4 and Table 5 present the ANOVA results of the two designs. In the two designs, we were looking forward to getting a high value for F and a low value for P, which will give an indicator that the results were significant.

Table4:ANOVA results of NEXT.

Source	F-value	p-value
model	30.72	< 0.0001
A-frequency	4.53	0.0341
B-width	63.31	< 0.0001
C-No of vias	1.03	0.3114
A^2	2.38	0.1238
C^2	0.0018	0.9664
A^2B	4.03	0.0457
A^2C	2.38	0.1243
AB^2	4.95	0.0268
AC^2	13.37	0.0003
B^2C	2.78	0.0964
BC^2	6.23	0.0131
A^3	6.39	0.0120
B^3	22.60	< 0.0001
C^3	39.71	< 0.0001

Table5:ANOVA results of FEXT.

Source	F-value	p-value
Model	110.92	< 0.0001
A-frequency	116.50	< 0.0001
B-width	0.0863	0.7692
C-No of vias	3.83	0.0512
AB	129.87	< 0.0001
AC	2.77	0.0971
BC	6.74	0.0099
A^2	57.55	< 0.0001
B^2	111.29	< 0.0001
C^2	10.65	0.0012
A^2B	2.92	0.0884
A^2C	7.34	0.0072
AB^2	10.21	0.0016

AC^2	5.24	0.0228
B^3	13.40	0.0003
C^3	0.0000	0.9950
A^2B^2	27.90	< 0.0001
ABC^2	10.87	0.0011
BC^3	10.96	0.0011
B^4	59.24	< 0.0001
C^4	29.71	< 0.0001

The F-value was used to measure the size of the variable's effects. The F-value of the first model is 30.72 and for the second model is 110.92, which implies that the models are significant and eventually suggests that the possibility of noise to cause an F-value is 0.01%. The probability (P-value) for the first model terms A^2, C^2, A^2B, A^2C, AB^2, AC^2, B^2C, BC^2, A^3, B^3, and C^3 and the second model terms AB, AC, BC, A^2, B^2, C^2, A^2B, A^2C, AB^2, AC^2, B^3, C^3 A^2B^2, ABC^2, BC^3, B^4, and C^4 are all significant. Correspondingly, the data for the first design presented in the tables suggests that it has the maximum F-value W (63.31) followed by the frequency (4.53) and finally the number of vias (1.03), respectively. These suggest that the reduction in NEXT is significantly due to the w followed by a frequency and number of vias, respectively. Whereas, for the second design, the data implies that the frequency has the highest F-value (116.50) followed by a number of vias (3.83) and finally the W(0.0863) and respectively. These findings suggest that the reduction in FEXT is owed significantly to the frequency followed by the number of vias and W, respectively.

R^2 gives an indicator of how much the actual value and the predicted values are close to each other. The values range between 0 and 1. The R^2 values for the first and second models are 0.5981 and 0.8869, respectively. This indicates that the model as fitted can explain 60% of the variability of the NEXT and 80% variability of the FEXT. For the first model, the predicted R^2 (0.5562) is in reasonable agreement with the adjusted R^2 (0.5786) having a difference of less than 0.2. Also, for the second model, the predicted R^2 (0.8690) is in reasonable agreement with the adjusted R^2 (0.8789), having a difference also less than 0.2. Equations (1and2)were generated from the two models designed through the Response Surface Methodology (RSM) technique. Both equations give the predicted values of NEXT and FEXT in terms of the actual factors, respectively. By using equation (1) the NEXT can be calculated using the three variables; frequency, the width of the horizontal piece of the serpentine guard, and the number of vias. While, to calculate the FEXT equation (2) can be used.

$$NEXT(dB) = -504.11 + 1001.85f + 5.23w - 0.23n - 789.32f + 0.01n^2 - 9.33f^2w - 0.23f^2n + 6.55fw^2 + 0.03w^2n + 211.80f^3 - 1.75w^3 - 0.003n^3 \quad (1)$$

$$FEXT(dB) = -844.63 + 969.44f + 1127.10w + 2.34n - 1462.49fw - 7.40fw + 0.33wn - 313.60f^2 - 439.22w^2 + 0.11n^2 + 531.06f^2w + 2.89f^2w + 69.43w^3 - 158.40f^2w^2 - 0.01fwn^2 - 10.09w^4 \quad (2)$$

Where f is the frequency (GHz), W is the width of the horizontal piece of serpentine and n is the number of vias.

To test and ensure that the two designs (NEXT and FEXT) can explain the actual and real results, diagnostic plots were performed. Figure7(a) and (b) show the graphs of the normality test of the residuals for the NEXT and FEXT, respectively. In these plots, the straight lines represent the predicted values while the small boxes are the actual simulated values. In the two graphs, the residuals (the difference between the actual and predicted values) lie on straight lines which indicate that the distributions of residuals are normal. Also, the p-values on the Anderson-Darling test in the two designs are < 0.005 and 0.005 for NEXT and FEXT, respectively. The values confirm that the two distributions are normal because the two values are greater than 0.005.

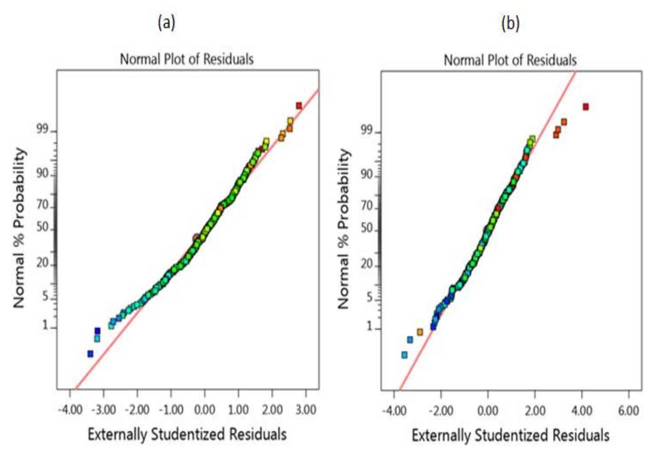

Figure7: Normality plot of the residuals for the (a) NEXT and (b) FEXT.

Figure 8(a) and (b) shows the plot of the predicted values against the actual values for the two responses (NEXT and FEXT) of the two designs. In these plots, the straight lines represent the predicted values while the small boxes are the actual simulated values. The actual values are located close to the straight line and have a high correlation coefficient, which confirm that the model is accurate to a large extent.

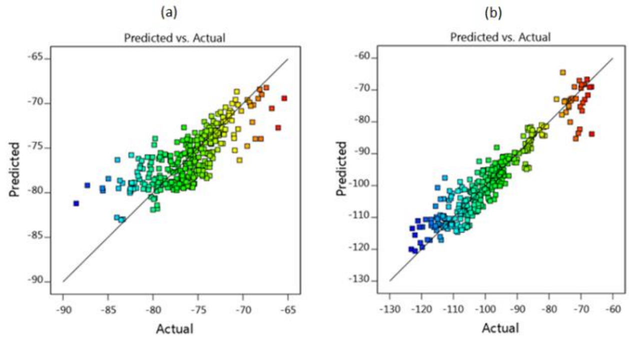

Figure8: Plots of predicted versus actual values for (a) NEXT and (b) FEXT.

Residuals versus predicted response for the first design (NEXT) and second design (FEXT) are presented in Figure9 (a) and (b), respectively. The graphs show that almost all points lie within area ± 3.0. This indicates that the assumptions of constant variance are confirmed, and the suggested models are suitable.

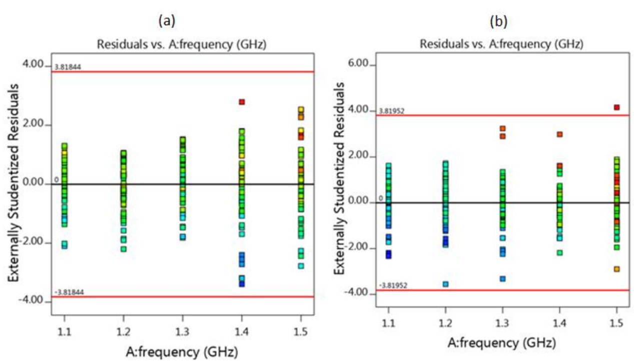

Figure9: Plot of residuals versus frequency for (a) NEXT and (b) FEXT.

D. Results analysis

In this section, we will analyze the results of NEXT and FEXT prediction. We will study the 2D and 3D surface plots of the relation between the response (NEXT and FEXT) and the three variables, number of vias, frequency, and width. Using the prediction model, a combination of the two variables (number of vias and frequency) at w=0.6 mm and two variables (w and frequency) in the absence of vias were plotted against the response value (NEXT).Figure 8(a) shows a two-dimensional (2D) contour plot for the interaction between the NEXT and number of vias and frequency. Whereas the width was fixed to 0.6 mm. Figure 10(b) shows the 2D contour plot for the interaction between the NEXT and the dual variables (width and frequency). Whereas the third variable (number of vias) was fixed to zero.

Figure 10(a) shows that the highest reduction of NEXT was around -80 dB (blue region). This value was realized when the number of vias was between 55 and 60 for the frequency range of 1.1 – 1.4 GHz and w =0.6. Figure 4.8(b) shows that the highest reduction of NEXT was around -75 dB (blue region). This value was realized when the width was between (0.6 and 1.2mm) for the frequency range (1.1 – 1.15GHz) in the absence of vias.

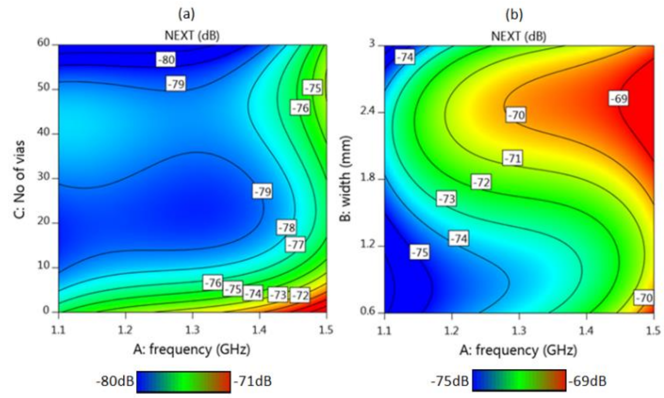

Figure10: 2D surface plots of the relation between the response (NEXT) and the two variables (a) number of vias and frequency (b) width and frequency.

Figure 11(a)and Figure11(b) presents three-dimensional (3D) surface plots for the interaction between NEXT and the dual variables (frequency and number of vias) and (frequency and width) for the first and the second graphs, respectively. From Figure 11(a), it can be seen that the highest peak (reduction of NEXT) was around -80 dB (highlighted in the dark blue region) which can be achieved when the frequency was between (1.1-1.35 GHz), the number of vias was between (5 and 60), and w was fixed to 0.6. Figure 11(b) reveals that the maximum peak (reduction of NEXT) was around -75 dB (dark blue region). This value was attained when the frequency was between (1.1-1.3 GHz)and thewidth was between (0.6 and 1.3mm) in the absences of vias.

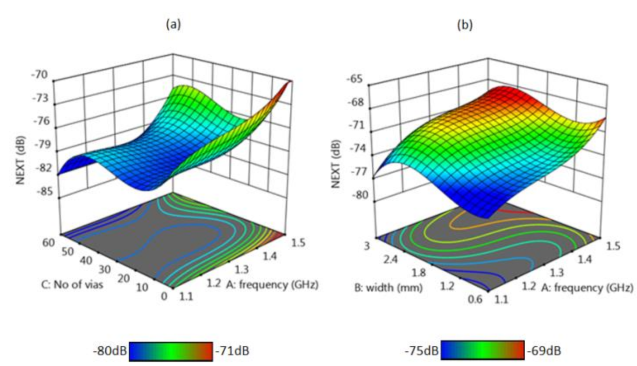

Figure11: 3D surface plots of the relation between the response (NEXT) and the two variables (a) number of vias and frequency (b) width and frequency.

Figure 12(a) shows the plots of 2D contour for the interaction between the response value (FEXT) and the dual variables (number of vias and frequency) where the third variable (width) was fixed to 0.6mm. The figure shows that the highest reduction occurs when FEXT was around -115 dB (dark blue region). This value was attained when the number of vias was between (5to 60) for the Frequency range (1.1 to 1.15GHz).

Figure 12(b) shows the plots of 2D contour for the interaction between the FEXT and the two variables (width and Frequency) where the third variable (number of vias) was fixed to zero. The Figure shows that the highest reduction occurs when FEXT was around -100 dB (dark blue region). This value was realized when the width was between (1.3 to 1.8mm) and the frequency range was between (1.1 and 1.15 GHz).

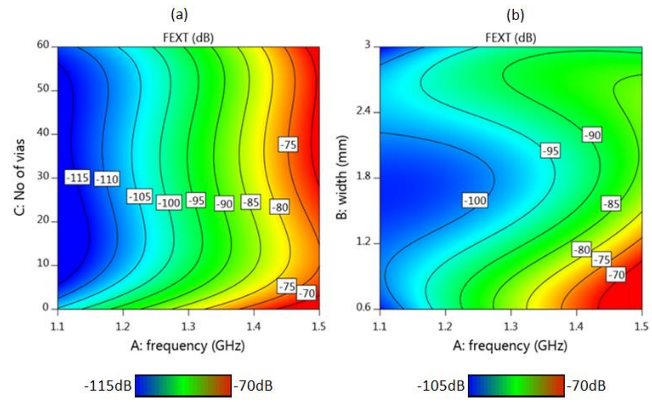

Figure12: 2D surface plots of the relation between the response (FEXT) and the two variables (a) number of vias and frequency (b) width and frequency.

Figure 13 (a) presents a 3D surface plots for the interaction between the response value (FEXT) and the two variables (number of vias and Frequency) where the third variable(w) was fixed to 0.6mm.The figure reveals that the maximum peak reduction occurs when FEXT was around -115 dB (dark blue region). This value was realized when the frequency range 1.1 to 1.15 GHz and number of vias was between (0to 60).

Figure 13(b) shows a 3D surface plots for the interaction between the FEXT and the two variables (width and Frequency) where the third variable (number of vias) was fixed to zero. The figure shows that the highest peak reduction occurs when FEXT was around -105 dB (highlighted in the dark blue region). This value was achieved when the width was between (1.3 to 1.8mm) and the frequency ranges was between 1.1 and 1.2 GHz.

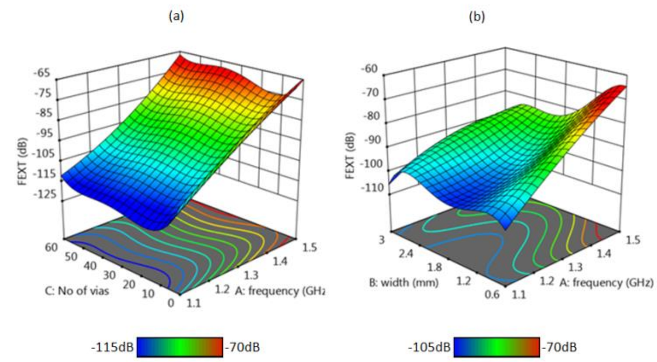

Figure13: 3D surface plots of the relation between the response (FEXT) and the two variables (a) number of vias and frequency(b) width and frequency.

E. Optimization

RSM has been used to optimize the NEXT and FEXT. In this methodology, numerical optimization was used. To find the optimum values for the NEXT and FEXT, we need to determine the conditions for the two designs to be followed. The input and output values were restricted by determining a set of goals as follows: for the two designs, the three variables A (frequency), B (w), and C (number of vias) were selected to be in the range option and for the two responses (NEXT and FEXT) to be minimum. Show the determined constraints used in the software for optimization for the two designs.

Table6:The constraints of the optimization for the NEXT design.

Name	Unit	Goal	Lower Limit	Upper limit	Lower weight	Upper weight
A: Frequency	GHz	In range	1.1	1.5	1	1
B: Number of vias	-	In range	0.6	5	1	1
C: w	mm	In range	0	70	1	1
NEXT	dB	Minimize	-88.5	-65.4	1	1

Table7:The constraints of the optimization for the FEXT design.

Name	Unit	Goal	Lower Limit	Upper limit	Lower weight	Upper weight
A: Frequency	GHz	In range	1.1	1.5	1	1
B: Number of vias	-	In range	0.6	5	1	1
C: W	mm	In range	0	70	1	1
FEXT	dB	Minimize	-123	-66	1	1

A list of the best possible solutions was generated by the software to get the optimum output (response). Table 8 shows some of the optimum conditions that were suggested from software to get the highest reduction of NEXT and Table 9 shows some of the optimum conditions for the second design to get the highest reduction of FEXT.

Table8:Optimum predicted values of NEXT.

Test no	Frequency (GHz)	W (mm)	Number of vias	Predicted NEXT (dB)	Desirability (%)
1	1.111	3.737	3.257	-89.036	1.000
2	1.110	3.964	14.259	-94.120	1.000
3	1.252	4.337	27.635	-97.455	1.000

Table9:Optimum predicted values of FEXT.

Test no	Frequency (GHz)	W (mm)	Number of vias	Predicted NEXT (dB)	Desirability (%)
1	1.260	3.433	17.667	-130.993	1.000
2	1.324	3.387	46.778	-139.700	1.000
3	1.462	3.442	9.194	-137.574	1.000

G. Conclusion

The Near-End and Far-End Crosstalk (NEXT and FEXT) for GPS transmission line in 5G smart phone were investigated in the frequency range of GPS of 1.1 to 1.5 GHz . In this work, a new design for SGT in the presence and absence of vias is proposed to reduce the crosstalk effect in GPS in 5Gsmart phones. The NEXT (S_{31}) and FEXT (S_{41}) were calculated using CST. Also, the parameters that affect the Crosstalk reduction were optimized using (RSM).

The results show that the values of NEXT and FEXT vary with frequency, horizontal segment width and the number of vias. The highest reduction of NEXT was achieved when SGTV with w equal to 0.9 mm was used. The highest reduction of NEXT and FEXT was achieved when SGTV with 0.9 mm width was used. By using SGT instead of rectangular GT the NEXT values reduced by around 25dB.Also when vias were added the NEXT values were reduced by around 33.8dB. While the FEXT values werereduced by around 11 dB with no vias and around 23 dB in the presence of vias.

From the electric field distribution, it is clear that using serpentine guard trace reduces the electric field intensity significantly comparing with conventional guard trace also by adding vias, the attenuation of the electric field increases suggesting a reduction in crosstalk. While, from magnetic field distribution, using serpentine guard trace reduces the magnetic field intensity more than the conventional guard trace also, by adding vias.

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