Signal Acquisition and Measurement System in Microwave Measuring Line Based on Compressed Displacement Sensor

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Abstract: The integrity of circuit board signals is largely influenced by the far end crosstalk among microstrip lines. To research the far end crosstalk-reduction method, the methods of RSR structure and adding dielectric layer are specifically researched in this paper on the basis of Ansoft HFSS software simulation software by building the microstrip line model and comparing the influences of crosstalk in different guard line situations. According to the S_{41} parametric variation curve obtained, the influences of the number of geometric parameters of metal patch in RSR structure on reducing the far end crosstalk are discussed. In addition, the influences of the thickness of the dielectric layer added above the microstrip line and the relative dielectric constant of material on reducing the far end crosstalk are also discussed.

1. Introduction

The integrity of circuit board signals is an increasingly prominent issue as the modern electronic devices are developing at high speed, high frequency and miniaturization. There will be electric field and magnetic field generally called the fringing field when the signals are transferred inside the microstrip line of the circuit board. If the other microstrip line is close to this one, it will be influenced by the fringing field, hence the crosstalk phenomenon. According to the crosstalk issue among the microstrip lines, scholars have adopted various methods to reduce the influences of crosstalk. In which, the most common method is to add the different shapes of ground guard lines into the microstrip lines. These shapes include the traditional guard line, ground via guard line, bending guard line etc. For instance, Lee et.al [1] reached the conclusion that the bending guard line can better reduce the influence of far end crosstalk by comparing the models without guard line, with common guard line, via guard line and bending guard line respectively; Li Liping et.al [2] researched the situation of adding the ground via on the guard line at regular intervals, during which it was pointed out that the distance among holes shall be smaller than the transmission distance of the signal within the time of RT/2 (RT refers to the rise time of the transmission signals), also the coupling noise will be reduced by increasing the width of guard line.

2. Calculation of S Parameter

S parameter is the network parameter based on the relationship of incident wave and reflected wave; Fig.1 is the diagram of the N port network. The incident power and reflected power related to port i can be defined as[12]:

$$\begin{cases} a_i = \dfrac{V_i + Z_i I_i}{2\sqrt{\left|\operatorname{Re} Z_i\right|}} \\ b_i = \dfrac{V_i - Z_i^* I_i}{2\sqrt{\left|\operatorname{Re} Z_i\right|}} \end{cases} \quad (1)$$

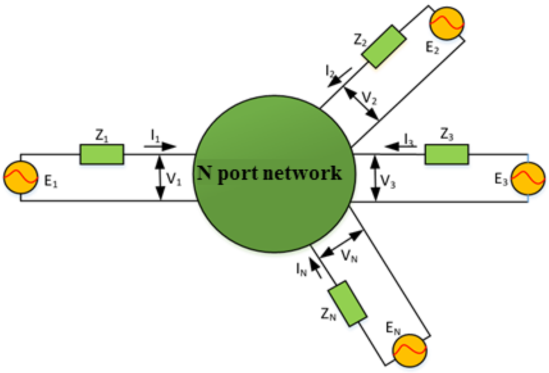


Fig.1 Diagram of N port network

For the microwave circuit, Z_i is always real number and quals to 50Ω, so that the S parameter matrix can be written down as:

$$\begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_N \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1N} \\ S_{21} & S_{22} & \cdots & S_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ S_{N1} & S_{N2} & \cdots & S_{NN} \end{bmatrix} \times \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{bmatrix} \tag{2}$$

S_{mn} is adopted to define the scattering parameters of the correlative ports, m is the output port and n is the input port. Assume only n port is the excitation port while other ports are matched load, then the output power of the output power of the output port is b_m, the input power of the input port is a_n, there will be:

$$S_{mn} = \frac{b_m}{a_n} \tag{3}$$

So that $S_{41} = \frac{b_4}{a_1}$, namely the ratio of the port 4 output power and the port 1 input power.

3. Model building and result verification

The double microstrip line being researched is as shown in Fig.2.

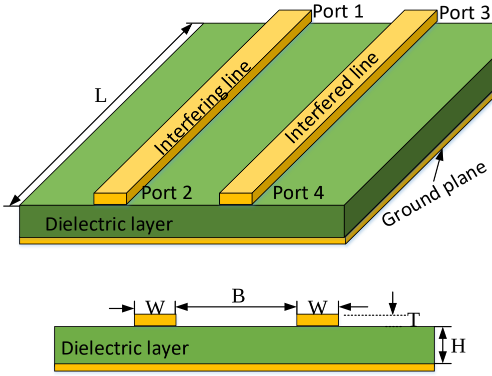


Fig.2 Diagram of double microstrip line model

The distance between two microstrip lines can be represented by B. The microstrip line is coppery, the relative dielectric constant is 0.999991 and the electrical conductivity is 5.8×10^{7} s/m. The physical dimension of the microstrip line shall be: the line width W=3mm, thickness T=0.035mm, length L=50mm. The baseplate material is FR4, relative dielectric constant is $\varepsilon_r = 4.4$ and the thickness is H=1.6mm. Port 1 is the excitation port while other ports are connected with the 50Ω match load. Compare the far end crosstalk S_{41} obtained with the result of document [11], CST Studio simulation result and FDTD simulation result, it can be seen from Fig. 3 that the simulation result can be better fitted.

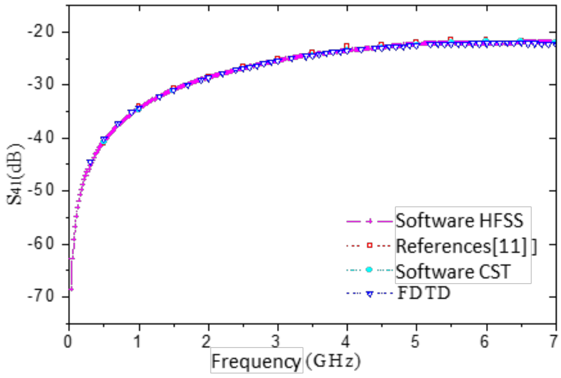


Fig.3 Comparison of S_{41} variation curves

4. Methods of Reducing the Far End Crosstalk

Currently, there are many methods to reduce the far end crosstalk; among which, it is common to increase the line spacing and adding the guard line etc. Fig.4 shows the variation curves of the far end crosstalk with different line spacings.

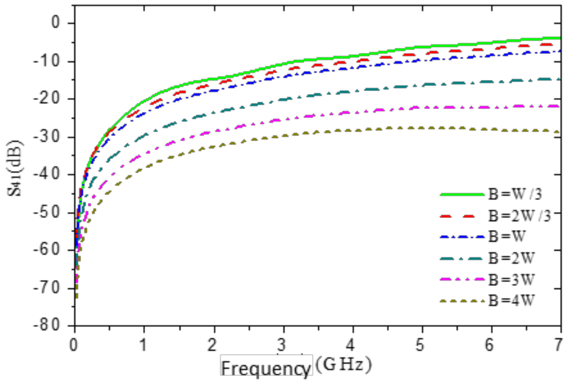


Fig. 4 Variations of far end crosstalk among microstrip lines with different B values

According to Fig.4, the far end crosstalk is reduced as the line spacing is increased. Compared with B=W/3, when B=3W, the amplitude of S_{41} is reduced by about 20dB; as the frequency increases, the difference will be larger. Therefore, it is an effective method to reduce the far end crosstalk by increasing the line spacing; however, this method has higher requirements for the circuit board volume, hence difficult to be implemented as the circuit board volume is limited.

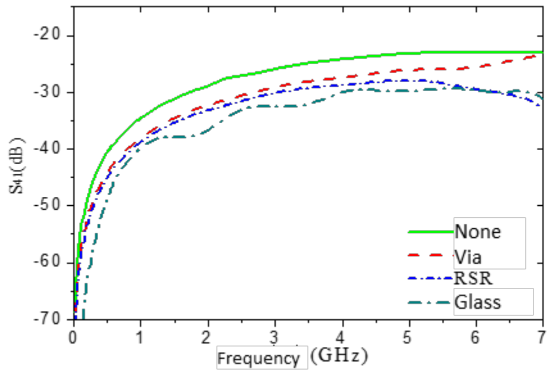
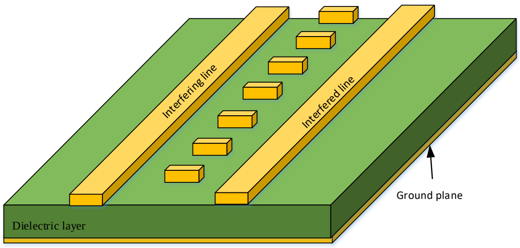


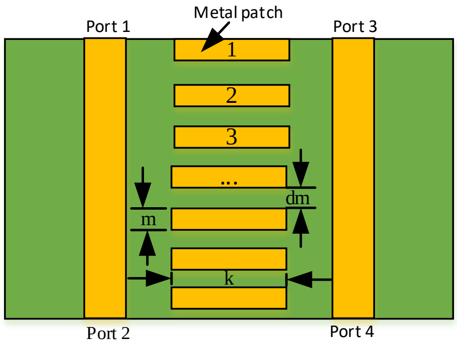
Fig.5 Comparison of three measures to reduce the far end crosstalk

Fig.5 is the comparison of the models without guard line, with via guard line, RST structure guard line and covered by 2mm-thick glass medium on the top (the relative dielectric constant is 5.5). It can be seen from Fig. 5 that the RSR structure guard line is better than the via guard line to reduce the far end crosstalk. The far end crosstalk can be better reduced by adding certain thickness of covered dielectric layer above the microstrip line.

The RSR structure guard line mentioned in this paper is as shown in Fig.6. Metal patches are evenly distributed among the microstrip lines and respectively numbered as 1,2, ……; the spacings between both ends and the interfering line and inferred line are the same. K, m and n are adopted to represent the length, width and height of the metal patch respectively while dm is adopted ti represent the distance among patches.



(a) Three-dimensional model



(b) Vertical view of the model

Fig.6 Diagram of RSR structure guard line

To research the influences of the length variation of metal patch on the far end crosstalk noise among the microstrip lines, 25 pieces of coppery metal patches are adopted with m=1mm,dm=1mm,n=0.035mm; changing the value of k, there will be the comparison chart of S_{41} variation curves with different k values as shown in Fig. 7.

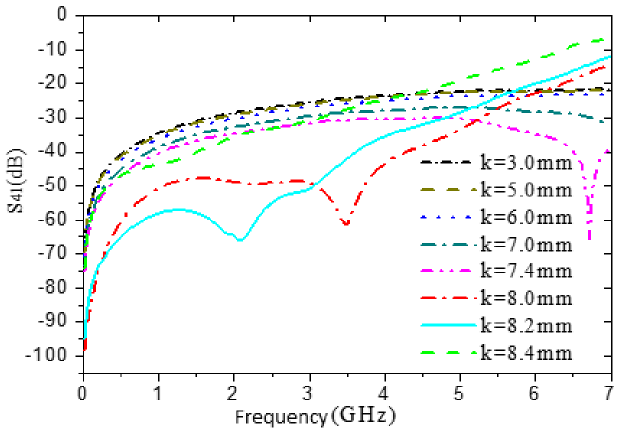


Fig.7 Comparison of S_{41} amplitude variations with different k values

According to Fig.7, when the metal patch length varies from 3 to 7.4 mm, the length is increased as the far end crosstalk is reduced; when the length is k=8mm, the frequency will be within the range of 0-5.2GHz, the S_{41} amplitude has been greatly reduced compared with that at k=3mm; the maximum reducing amplitude can be about 35dB; when the frequency is within the range of 5.2GHz-7GHz, the S_{41} value will be increased to larger than the value at k=7.4mm; when k=8.2mm, the S_{41} value within the frequency range of 0-3.1GHz has been less than -50dB. When the length is continuously increased to 8.4mm, the S_{41} amplitude rises again somewhat and its value will be rapidly increased within the frequency range of 2.5-7GHz. Therefore, when designing the RSR structure guard line, to reduce the influences of far end crosstalk as far as possible, within the relatively lower frequency range, the length of metal patches shall be increased to the largest extent to reduce the far end crosstalk; what's more, there will be the optimal length value. Within the relatively higher frequency range, the length of metal patches shall not be too large.

Eliminate the metal patches numbered 2, 4, …, 24 with 23 pieces left. Eliminated those numbered 3, 7, …, 23 with seven pieces left; eliminate metal patches numbered 5, 13, 21 with four pieces left to obtain the final comparison curve as shown in Fig.8. according to which, it can be seen that as the number of metal patches is reduced, the S_{41} amplitude will rise somewhat. Within the low frequency range, the influences of far end crosstalk can be greatly reduced by adding the number of metal patches.

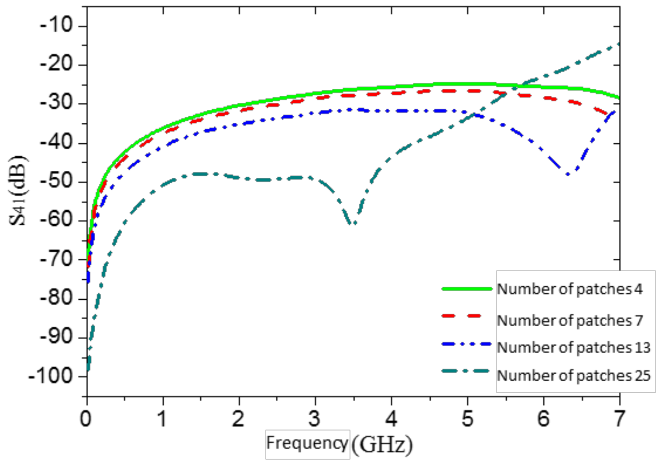
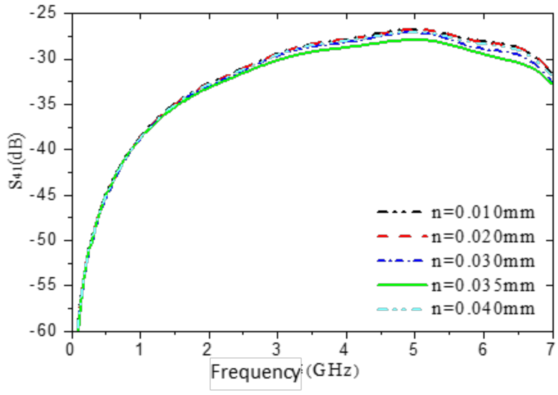
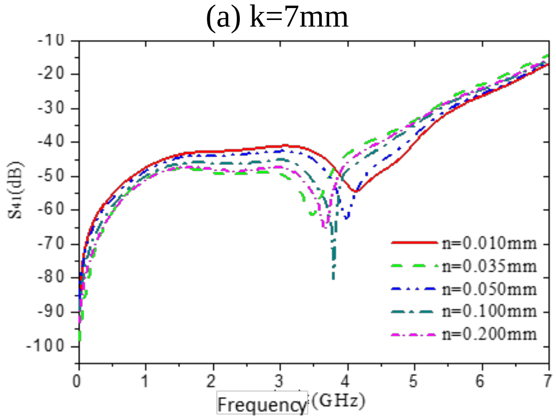


Fig. 8 Relation schema of S_{41} variations corresponding to different numbers of metal patches



(a) k=7mm



(b) k=8mm

Fig. 9 Relation schema of S_{41} variations corresponding to different thicknesses of metal patches

25 pieces of metal patches at k=7mm and k=8mm are adopted, only the thickness of metal patches is changed while other parameters remain unchanged to obtain the variation curve of S_{41}

amplitude along the frequency as shown in Fig.9. According to Fig. 9 (a), it can be seen that when the patch thickness is n=T=0.035mm, the S_{41} amplitude is the minimum. According to Fig. 9 (b), it can be seen that within the frequency range of 0-3.5GHz, the S_{41} amplitude corresponding to n=0.035mm is the minimum, while within the frequency range of 4-7GHz, the S_{41} amplitude corresponding to n=0.01mm is the minimum. The two charts in Fig.9 indicate that if the material of the selected metal patch is the same with that of the microstrip line, in the RSR structure guard line, within a certain frequency range, the thickness of the metal patch shall be equivalent to that of the microstrip line if possible to reduce the influences of the far end crosstalk.

5. Conclusion

Through the simulation research on the influences of the RSR guard line structure dimension and the covered dielectric layer thickness on the microstrip line far end crosstalk, it is discovered that the influences of far end crosstalk can be reduced effectively by adding both the guard line and covered dielectric layer among the microstrip lines. Under the preset structure parameters, when the frequency is 0-3GHz, the influences of far end crosstalk can be reduced by adding the length and number of metal patches in the RSR structure as well as the thickness of covered dielectric layer and the relative dielectric constant. In other frequency ranges, the optimal settings of parameters shall be determined according to the specific signal frequencies. In the PCB design, if the RSR guard line is adopted, the number of metal patches shall be increased and the appropriate length shall be selected to reach the satisfying effect of reducing the far end crosstalk. The research result in this paper is of certain guiding and reference significance to the design and wiring of the high-frequency circuit.

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