# Comparative Study of Radiated Emission in Various Microstripline Structures on Printed Circuit Boards

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**Abstract:** ***The enormous advancement in science and technology has led to increase in the requirements for high speed data transmission. The increase in the speed of the digital circuits as well as the density of printed circuit board will often result in more challenging signal integrity issues. One of the most important signal integrity issues is radiated emission. We analyzed the radiation in different PCB structures like parallel microstripline, a 90° bend microstripline and serpentine microstripline. The radiation mechanism from various PCB structures is predicted and simulated by using Ansoft HFSS. Simulated results are compared with the existing structures.***

**Keywords**: Signal Integrity, Radiated Emission, PCB, Microstriplines

## 1. Introduction

There has been a drastic progress in wireless communication which has led to the miniaturization of circuits. Due to the reduced size and complexity of the circuits, signal integrity issues posed many challenges to the circuit designers. Signal Integrity is a measure of the quality of the electrical signal. Signal Integrity ensures that all signals are transmitted and received correctly. It also ensures that signals don't interfere with each other. Signal integrity addresses two issues namely, the quality and the timing of the signal. Inside a system, the signals will travel through different interconnections. The timing and quality of the signal is affected by the electrical impact at the source end and the receiving end. The signal integrity issues are crosstalk, radiated emissions, ringing, ground bounce and power supply noise. The most important signal integrity issue is radiated emission.

## 2. Literature Survey

The term radiated emission refers to the unintentional release of electromagnetic energy from a device. It also refers to the interference that is coupled through air. Electronic devices having significant amounts of radiated emissions may interfere with the normal operation of other devices kept in close proximity. Various organizations and agencies regulate the allowable radiated emissions from the electronic modules. The major source of radiated emission in high speed printed circuit board is the common mode current. The currents on parallel conductors can be divided into two types- common mode current and differential mode current. Differential mode currents are equal in magnitude, but opposite in direction on parallel conductors. The common mode currents are equal in magnitude and direction on parallel conductors. The differential and common mode currents are shown in figure 1.

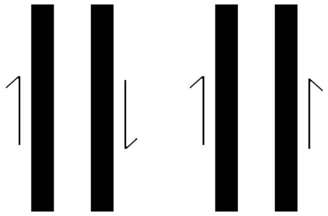


**Figure 1.** Differential and common mode currents

In general, an arbitrary current on a parallel conductor system comprises of differential and common mode currents. Let the common mode current and differential mode can be represented as $I_C$ and $I_D$ respectively. Let the current on the first conductor be $I_1$, which can be represented as the sum of common mode and differential mode currents.

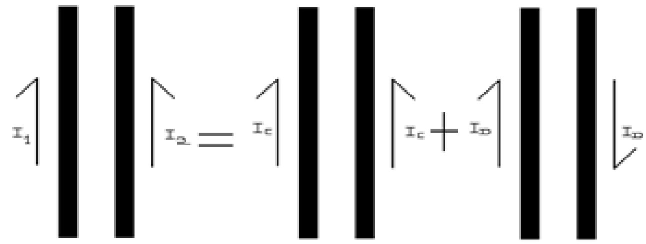
$$I_1 = I_C + I_D \quad (1)$$

Let the current on the second conductor be $I_2$, which can be represented as the difference between the common mode and differential mode currents.

$$I_2 = I_C - I_D \quad (2)$$

Thus, the common mode and differential mode currents are found to be

$$I_C = (I_1 + I_2) / 2 \quad (3)$$
$$I_D = (I_1 - I_2) / 2 \quad (4)$$



**Total current** **Common mode Current** **Differential mode Current**

**Figure 2.** Decomposition of total current into common mode and differential mode currents

As shown in figure 2,

**Total current = Common mode current + differential mode current**

The radiated electric field components due to differential mode currents subtract, producing a small net radiated electric field. The radiated electric field components due to common mode currents add, producing a much larger net electric field. Hence the major cause of radiated emission is common mode current. For high frequency applications, the common mode and differential mode currents should be considered because of the square relation between the emission and operating frequency.

There are number of ways of estimating the radiated emissions. Radiated emissions can be estimated by using imbalance difference method [1] in which all the differential mode sources are converted into common mode sources. The simulation tool used is full wave simulator. The main advantage is that this model does not require antenna impedance measurement. Even though the I/O line and the dielectric layer play a very important role in crosstalk calculation, these two parameters are not used in this model. Also, the radiated emission in straight and bent microstripline can be estimated by using expanded hertzian dipole approach and the results are compared with the simulation results of Microwave Studio. In this approach, the bent microstripline is divided into a number of cascaded short uniform dipoles. The sum of all the electric fields from each dipole element of the line gives the electric field for the entire bend. The results reveal that the straight microstripline show better results than the bent microstripline [2]. Also, the radiation is higher, when the structure is not perfectly matched.

The radiated emissions from the edges can be reduced by Stitching, Stitching is a technique in which the ground planes are stitched together within the board using closely spaced vias. The stitching was performed in a PCB model consisting of two parallel plates [3]. Stitching produces resonance and internal reflections. These internal reflections and resonance can couple to the internal board traces, thus increasing the signal crosstalk. The radiated emissions can also be reduced by decreasing the distance between the signal trace and ground plane [4], which is done by providing additional low impedance for the signal current and by placing the image plane above printed circuit board. The other methods for reducing the radiated emissions includes using symmetric ground plane [5], ground guard fence [6] and by using novel ground planes [7]. Also the radiated emission from a differential pair is much lower than that of the single ended transmission line [8].

The far-field radiation of a single-ended microstrip line with arbitrary terminal load is given by [8]

$$E(r) = \frac{\omega\mu_0}{4\pi}\,\frac{e^{-jk_0r}}{r}\,\frac{V_S}{Z_S+Z_C}\,\frac{1}{1-\rho_S\rho_L e^{-j\beta 2l}}\ \mathrm{X}\ \left\{F_x\left[\frac{1-e^{-j(\beta-k_x)l}}{\beta-k_x}+\rho_L\,e^{-j\beta 2l}\,\frac{1-e^{-j(\beta+k_x)l}}{\beta+k_x}\right]+jhF_z\left[1-\rho_L e^{-j\beta 2l}-(1-\rho_L)e^{-j(\beta-k_x)l}\right]\right\}$$

(5)

The far-field radiation of a pair of parallel microstrip traces driven by the common mode current is given by,

$$E_{CM}(r) = 2\cos(k_0d)\ X\ \frac{e^{-jk_0r}}{r}\quad X\quad \frac{\omega\mu_0}{4\pi}\,\frac{V_S}{Z_S+Z_C}\,\frac{1}{1-\rho_S\rho_L\,e^{-j\beta 2l}}\quad X\quad \left\{F_x\left[\frac{1-e^{-j(\beta-k_x)l}}{\beta-k_x}+\rho_L\,e^{-j\beta 2l}\,\frac{1-e^{-j(\beta+k_x)l}}{\beta+k_x}\right]+jhF_z\left[1-\rho_L e^{-j\beta 2l}-(1-\rho_L)e^{-j(\beta-k_x)l}\right]\right\} \tag{6}$$

The far-field radiation of a pair of parallel microstrip traces driven by the differential mode current is given by

$$E_{DM}(r) = 2j\sin(k_0d)\ X\ \frac{e^{-jk_0r}}{r}\quad X\quad \frac{\omega\mu_0}{4\pi}\,\frac{V_S}{Z_S+Z_C}\,\frac{1}{1-\rho_S\rho_L\,e^{-j\beta 2l}}\quad X\quad \left\{F_x\left[\frac{1-e^{-j(\beta-k_x)l}}{\beta-k_x}+\rho_L\,e^{-j\beta 2l}\,\frac{1-e^{-j(\beta+k_x)l}}{\beta+k_x}\right]+jhF_z\left[1-\rho_L e^{-j\beta 2l}-(1-\rho_L)e^{-j(\beta-k_x)l}\right]\right\} \tag{7}$$

A bent transmission line radiates a part of the input power and that radiation loss was determined to be on the order of 10% of the input power. When a straight line without a bend is considered, the radiation loss was about 6-7% of the input power [9].

## 3. Previous Work

The previous approaches for reducing the radiated emission includes the usage of various microstripline structures like single trace microstripline, parallel microstripline and bent microstripline.

### 3.1 Parallel Microstripline

Due to the reduced size of circuits with integrated semiconductor electron devices, a transmission line structure was required that was compatible with the circuit construction techniques to provide guided waves over limited distances. This was realized with the help of a planar form of transmission line over a ground plane, called microstripline. Microstripline structure is the most basic structure and is widely used in printed circuit board applications because they are inexpensive and easy to manufacture. Microstripline employs a flat strip conductor suspended above a ground plane by means of a low loss dielectric material.

A parallel microstripline is constructed by placing two signal traces adjacent to each other. The space between the parallel microstriplines is extremely limited in high density circuits and it leads to signal integrity issues like crosstalk.

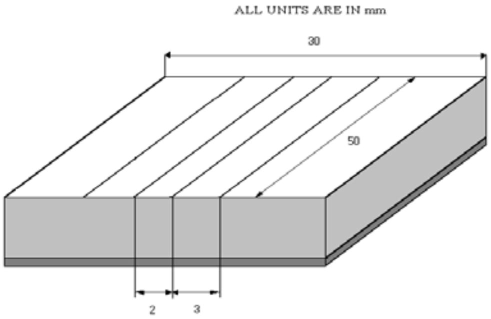


**Figure 3.** Parallel microstripline

### 3.2 Bent Microstripline

It was reported that a transmission line with a bend will radiate some of the input power and it results in radiated EMI [9]. With the bend angle of 90°, the loss was about 11%.This shows that radiated emission increases with sharper bend angles. But the radiated emission from two microstripline of 90° bend and two 45° bends are identical [10].

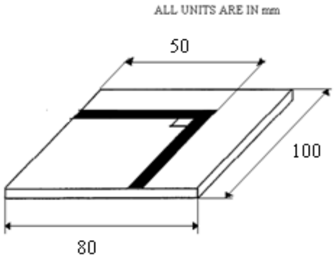


**Figure 4.** A 90° Bent microstripline

## 4. Problem Definition

The increased speed and density of the high performance circuit has posed many challenges to the circuit designer and it has generated unintentional electromagnetic emission between components, devices and printed circuit board transmission lines. Hence there is a need for reducing the unintentional electromagnetic emission from the devices by a suitable and cost effective design.

## 5. Proposed structure for the reduction of radiated emission

It has been found in a research that the cross talk problem in printed circuit board can be reduced to a larger extent using serpentine microstripline [11]. Hence, the proposed structure for reducing radiated emission is serpentine microstripline. If the radiated emission is less, it could be used for effective printed circuit board design.

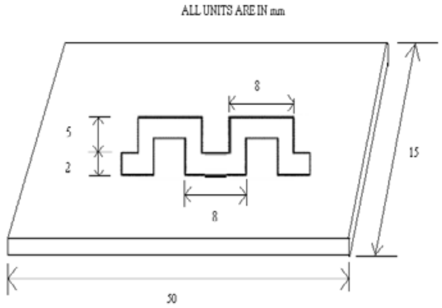


**Figure 5.** Serpentine microstripline

## 5. Results and Discussions

Ansoft HFSS was employed to model the geometries of the above mentioned transmission line structures.

### 5.1 Microstripline:

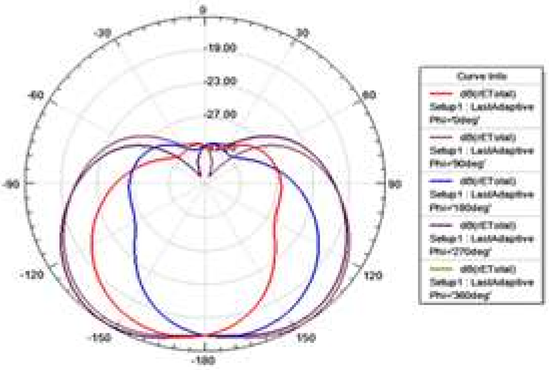


**Figure 6.** Radiation Pattern of microstripline

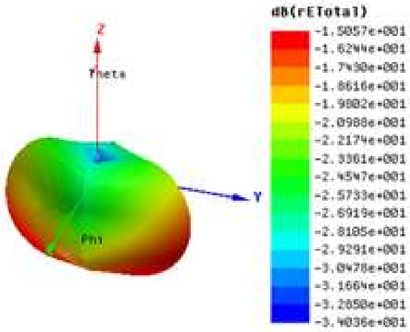


**Figure 7.** 3D plot of radiation pattern

The microstripline with the dimensions 50mmx30mmx 1.6mm is designed. The trace on the top layer is 3mm wide and 50mm long. The substrate material is fr4 epoxy which has a relative permittivity of 4.4. The radiation pattern of the structure is shown in figure 7 and 8. The maximum E field obtained in case of single trace microstripline is -31.6dB.

### 5.2 Parallel Microstripline

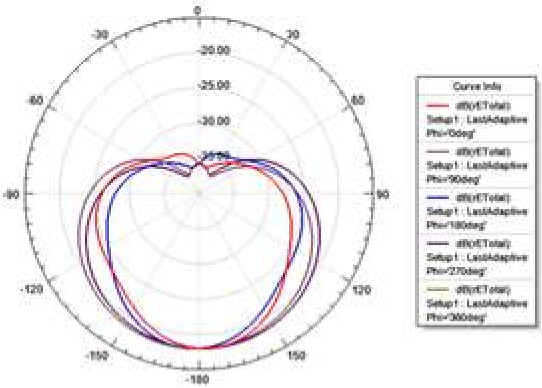


**Figure 8.** Radiation pattern of parallel microstripline

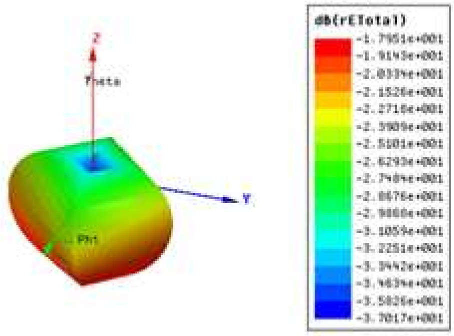


**Figure 9.** 3D plot of radiation pattern

The parallel microstripline with the dimension 50mmx30mmx1.6mm is designed. The traces on the top layers are 3mm wide and 50mm long. The two signal traces are separated by a distance of 7mm. The radiation pattern of the structure is shown in figure 8 and 9. The maximum field obtained in case of parallel microstripline is -35.6dB.

### 5.3 A 90° Bent microstripline

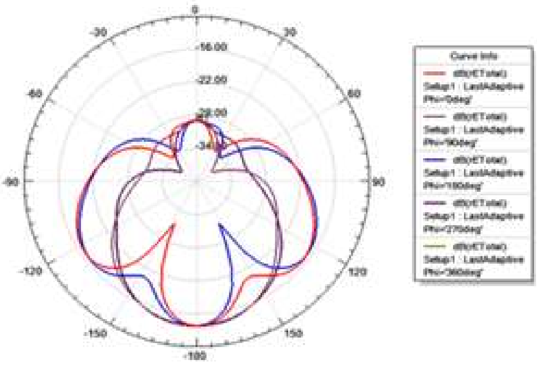


**Figure 10.** Radiation pattern of a 90° bent microstripline

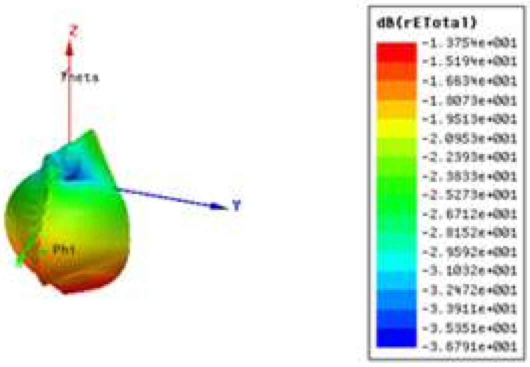


**Figure 11.** 3D plot of radiation pattern

The 90° bent microstripline with the dimension 100mmx80mmx1.3mm is designed. The bend angle is 90°. Each of the trace is 50mm long and 3mm wide. The simulated results are presented in figure 10 and 11. The maximum E field obtained is -28.62dB.

### 5.4 Two 45° Bent microstripline

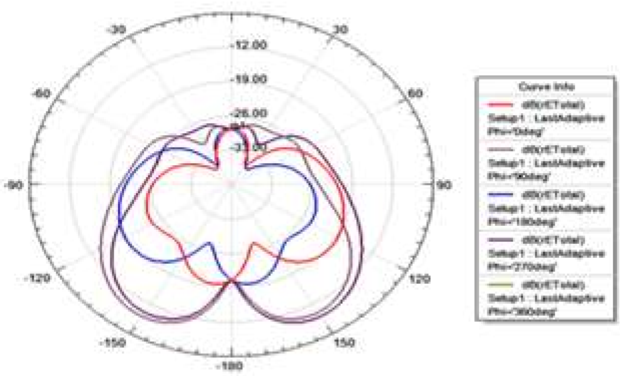


**Figure 12.** Radiation pattern of a two 45° bent microstripline

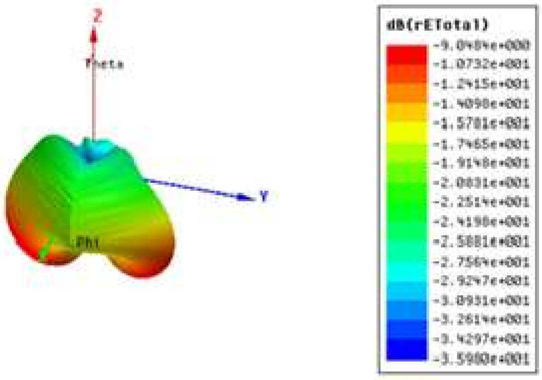


**Figure 13.** 3D plot of radiation pattern

The two 45° bent microstripline with the dimensions 100mmx80mmx1.3mm is designed. Each of the trace is 50mm long and 3mm wide. The simulated results are presented in figure 13 and 14. The maximum E field obtained is -28.68dB.

### 5.5 Serpentine Microstripline

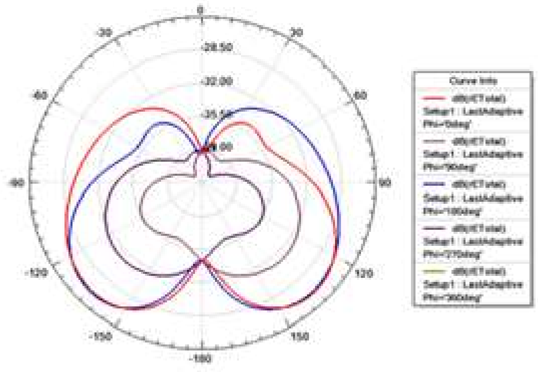


**Figure 14.** Radiation pattern of serpentine microstripline

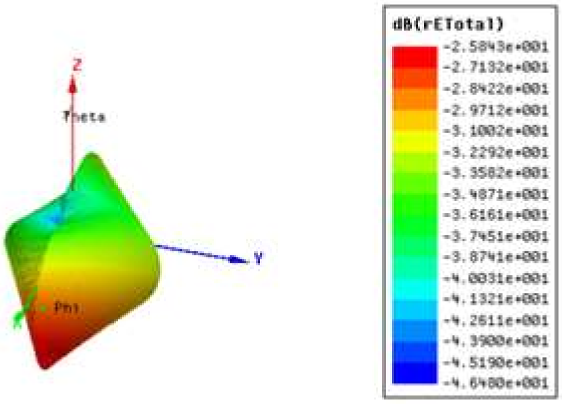


**Figure 15.** 3D plot of radiation pattern

The serpentine microstripline with the dimensions 50mmx30mmx1.6mm is designed. Each bend is 5mm long and 2mm wide. The distance between two bends is 8mm. The radiation pattern is shown in figure 14 and 15. The maximum E field is -39.1dB.

The results are summarized below:

**Table 1.** Comparison of maximum E field of various microstripline structures

| *Structures* | *Maximum E field(dB)* |
|---|---|
| Single trace Microstripline | -31.6 |
| Parallel Microstripline | -35.6 |
| 90° bent Microstripline | -28.62 |
| Two 45° bent Microstripline | -28.68 |
| Serpentine Microstripline | -39.1 |

## 6. Conclusion

The radiated emission from various microstripline structures like single trace microstripline, parallel microstripline, 90° bent microstripline, two 45° bent microstripline, serpentine microstripline was analyzed. The reduction of radiated emission can be accomplished by using serpentine microstripline. The future work will be concentrated on finding a more suitable structure for the reduction of radiated emission to a larger extent.

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