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Fast Finite Difference Time Domain Analysis of Microstrip Patch Antennas

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1 Abstract

Although the Finite Difference Time Domain (FDTD) method has been successfully used to model microstrip fed patch antennas, this has been achieved using uniform grids. This contribution will show that by using non-uniform grids, in conjunction with 1st order absorbing boundaries and broadband excitation, a drastic reduction in computation time can be achieved. Comparison with published data shows no loss in accurracy.

2 Theory

The computation time for an FDTD model is almost proportional to the number of nodes used. As a patch antenna is a highly resonant structure, the time sequence required to find the first few modes is long, and so requires a large number of iterations. Thus in order to keep the run time short, it is important to use as few nodes as possible. One way to achieve this is to use non-uniform grids. These grids concentrate the nodes in areas of large field variation, to maintain resolution, but not in areas of small field variation. Non-uniform grids have already been used successfully in the modelling of MMIC structures [1].

The non-uniform grid algorithm used here is the same as in [1]. The grid is divided into regions of varying length, each region containing four equally spaced nodes. Figure 1 shows how the regions concentrate the nodes about the metal edges where the field strengths vary rapidly over short distances. For the results included, the region lengths were chosen to keep the space step at the metal edges less than $\lambda/20$ and the maximum space step in the entire mesh less than or equal to $\lambda/10$, where λ is the shortest wavelength component in the excitation.

In [2], a 7.5GHz patch was modelled using a grid uniformly spaced along the axes but the space step in each axis varied. This model required 96k nodes. If the non-uniform grid algorithm is applied to the same patch only

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17.9k nodes are needed, resulting in an 80% reduction in nodes. However the time step for both algorithms is the same.

The other adaptations to the FDTD, model and the form of analysis used for the results presented here are as follows.

In the model of [2] the grid was positioned such that the tangential electric field components lay exactly on the metal edges. However [1] has shown that the field is more accurately represented by placing the metal so that it protrudes into the node space δx by the amount $\delta = \frac{1+\sqrt{5}}{4}\delta x$.

Several authors, including [2], when analysing microstrip structures, separate the incident and reflected pulses as follows. Firstly the feedline is modelled, without the patch, as an infinite line with the same grid and time step. From this the incident pulse is easily obtained as there is no discontinuity to cause reflections. Once the complete structure of patch and feedline has been modelled, this incident pulse is subtracted from the time sequence to give the reflected pulse. The results presented here were obtained by placing the probe sufficiently far away from the patch so that the incident and reflected pulses could be separated by 'windowing in' on the two pulses, thus removing the need for the short pre-simulation run.

The excitation consisted of a gaussian pulse truncated after $3T$, where the time constant T was set by the frequency range of interest. This pulse was used to excite a plane of nodes under the feedline, just in front of a 1st order absorbing boundary [3]. The highest frequency contained in the pulse, for defining the grid spacing was taken as the highest frequency of significant power within the pulse.

3 Results

The results obtained by modelling the antenna of [2] with the non-uniform grid are shown in figures 2 and 3. As can be seen both models produce results close to the measured data, except that the non-uniform model is closer to the measured data at around 18GHz. This improvement in accurray is probably due to the treatment of the metal edges. The complete simulation took 3.9hrs CPU time on a Gould 1.4Mflop multi-user machine. The simulation of patch and feedline in [2] took 12hrs on a 3500 Vax workstation.

A further reduction in the number of nodes used can be achieved by using correction factors [4] at the metal edges. This means that less nodes are needed at the metal edges.

4 Acknowledgements

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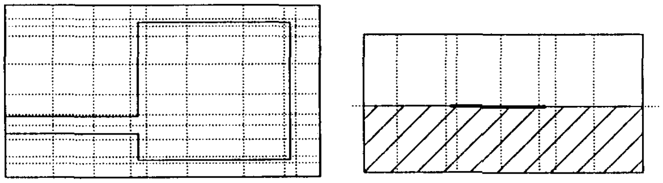

Figure 1 Splitting of the Antenna into regions

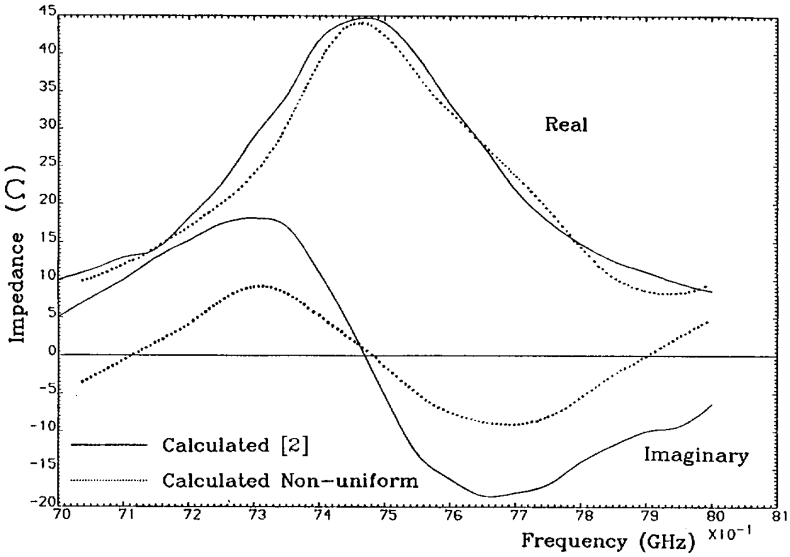

Figure 2 Input Impedance of Antenna at the Patch

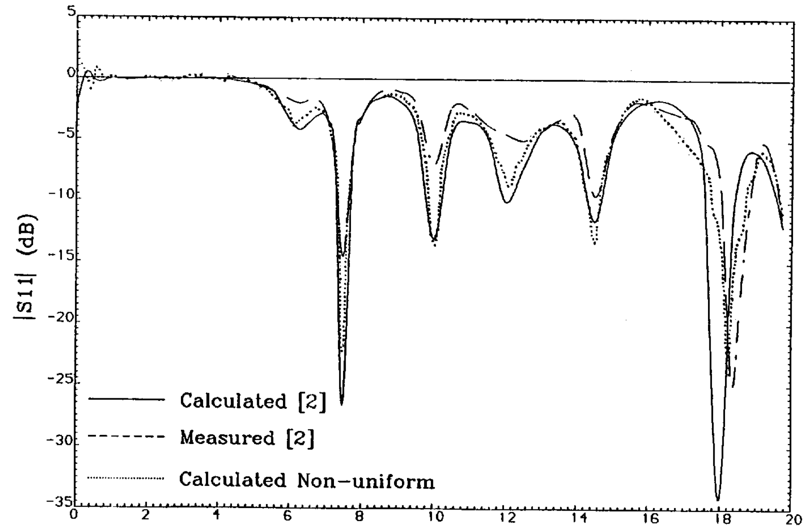

Figure 3 Return Loss of the Antenna