# Different Numerical Modelling Techniques for Multi-Layered Microstrip Patch antenna

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**ABSTRACT**

This paper describes numerical modelling of a dual band multi-layered microstrip patch antenna operating at 35GHz on an in-house semi-insulating GaAs substrate. The simulated and measured resonant frequencies at both lower and upper resonant frequencies will be compared to check the accuracy of the different numerical modelling techniques.

**INTRODUCTION**

Recently, the use of microstrip antennas somehow modified to act as dual-band elements has received much attention. One variation is a multi-layered patch structure which can be used as a multi band antenna for the systems where weight, cost and conformability are critical factors.

A multi-layered patch antenna fabricated at King's College London has been modelled numerically in this paper. The antenna is basically built on a thick GaAs substrate by stacking patch radiators one above the other with inserting very thin dielectric layers, as shown in Fig. 2 [1]. It poses a challenge to the numerical modeling due to its very thin structure involving inhomogenous media (Polymide layers and GaAs substrate) and the vertical coupling pin. It was initially modelled by using a MoM (Method of Moments) code, known as em developed by Sonnet [3]. However, it is noticed that there are quite some discrepancies between the numerical predication and the experimental measurement, as shown in Fig.3 and Table 1 [1]. Hence, further modelling on this multilayered patch antenna has been carried out by using a FD-TD (Finite Difference – Time Domain) code known as MAGIC [4]. Later on the antenna has been modeled again by using an alternative MoM code called MSTRIP40 [6] and Finite Element Method (FEM) code called HP-HFSS.

**NUMERICAL MODELLING AND COMPARISON**

The configuration of the multi-layered patch antenna fabricated at King's College London is shown in Fig. 2. It consists of five layers on top of a 400 µm thick S.I. GaAs substrate with a dielectric permittivity of 12.85. The first, third and fifth layers are metal with a thickness of 1 µm, 1 µm and 3 µm respectively, while the second and fourth layers are polymide ($\varepsilon_r$ = 3.4) with a thickness of 2 µm. The feed line (on metal 1) above the substrate is connected to the lower patch (2.200x1.718 mm on metal 2) via a vertical pin. The upper patch (1.800x1.718 mm on metal 3) is coupled parasitically with the lower patch.

A FD-TD code known as MAGIC (4) is used to model the multi-layered patch antenna depicted in Fig. 2. As mentioned in earlier, very small cells have to be employed in order to model thin polymide layers properly. This results in a very small time step (0.02ps) as in FD-TD the time step is determined by the dimension of the smallest cell. In the time domain analysis, the frequency response or resonance spectrum can only be obtained by applying FFT (Fast Fourier Transformation) to a time domain signal sampled in the simulation region. In order to obtain a full picture of the responding spectrum it needs to record the sampled signal up to several nanoseconds. Such an arrangement would require extremely

long simulation time, which deems the simulation impractical and renders the FD-TD approach a daunting task. However, by scaling up the dimensions of the antenna by a factor of 7.27, it allows the use of larger, hence a longer time step.
Eventually FD-TD modeling can be carried out within a reasonable length of simulation time. For the same reason of arguments, only part of the GaAs dielectric below metal 1 is included in the simulation as the electric field is not capable of permeating deep into the semi-insulating GaAs substrate. The whole model is also wrapped up with absorbing boundaries so as to absorb the emitted waves with minimum reflections.

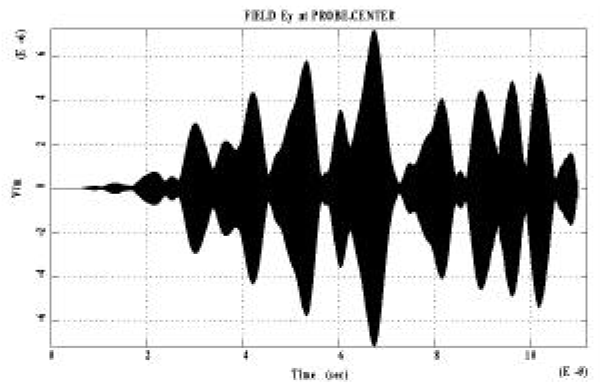


**Figure 1: $E_y$ field intensity waveform at a point between metal 2 and metal 3**

A Gaussian pulse having a flat frequency response over the frequencies of interest was injected at the input end so as to resonate the multi-layered patch antenna. The *E* field intensity at a point located between metal 2 and metal 3 is recorded in the time domain, shown in Fig. 1 and its corresponding spectrum obtained through FFT. Both the first and the second resonant frequencies are obtained from the simulation. However, the code is not capable of generating S parameter plots automatically.

The experimental results are compared to the computational simulation results using both MoM technique and FDTD technique, as shown in Table 1. It is found that MoM modeling over-estimates the first and second resonant frequencies by 2.2 GHz and 1.6 GHz, respectively. The results obtained through FD-TD modeling are found to be closer to the experimental results. FD-TD modeling also over-estimates the first and second resonant frequencies, but only by 0.86 GHz and 1.00 GHz, respectively.

Furthermore, the antenna is modelled by using an alternative MoM code, MSTRIP40, which is capable of accounting for different medium in the structure. The modeled resonant frequencies are shown in the fourth row in Table 1. It is noticed that the simulated resonant frequencies are even closer to the experimental ones. The simulated input return loss curve as shown in Fig. 4 also agrees well with the measured one, indicating that the first resonance is the major one. Frequency domain FEM (Finite Element Method) code called HP-HFSS[2] have been used to model the multi-layered antenna and results were compared as shown in the fifth row in Table 1.

**CONCLUSIONS AND DISCUSSIONS**

It is has been demonstrated that a better predication of the resonating frequencies of a multi-layered patch is achieved by using a FD-TD code MAGIC,FEM code called HP-HFSS and a MoM code MSTRIP40.

The resonant frequencies predicted from em(MoM) simulations are far away from the experimental ones. This was due to computing limitations and approximations made 6 years ago. The FDTD simulation results were much closer to that of the measurements, however, it has intrinsic difficulties in dealing with high-Q resonant circuits and extremely small structure. It can be seen that MSTRIP40 (MoM) achieves a much better prediction and the slight differences due to the approximation made on the feeding during the simulation.

## ACKNOWLEDGEMENT

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| | Resonant Frequency 1 | Resonant Frequency 2 |
|---|---|---|
| Experimental | 35.50 GHz | 39.00 GHz |
| em (MoM) | 37.70 GHz | 40.60 GHz |
| MAGIC (FD-TD) | 36.36 GHz | 40.00 GHz |
| MSTRP40(MoM) | 35.00 GHz | 39.50 GHz |
| HP-HFSS(FEM) | 34.60GHz | 39.10GHz |

**Table 1 Comparison of resonant frequencies obtained through the measurement, MoM and FD-TD modelling**

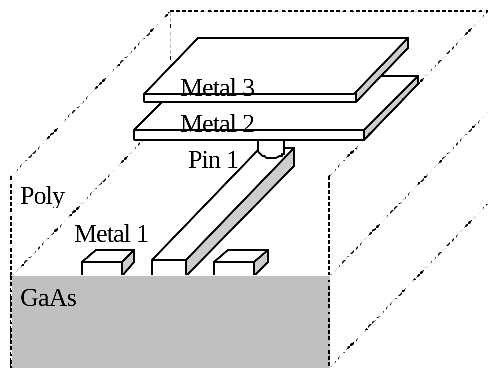


**Fig. 2 Configuration of the multi-layered patch antenna**

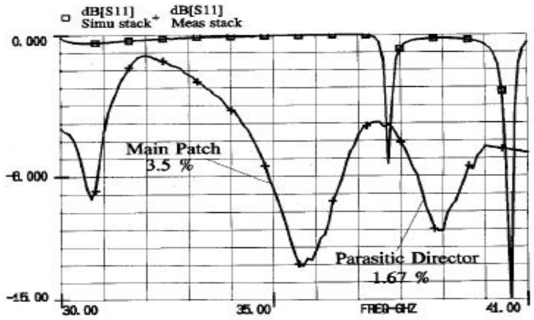


**Fig. 3 Simulated (em) and measured input stacked patch antenna**

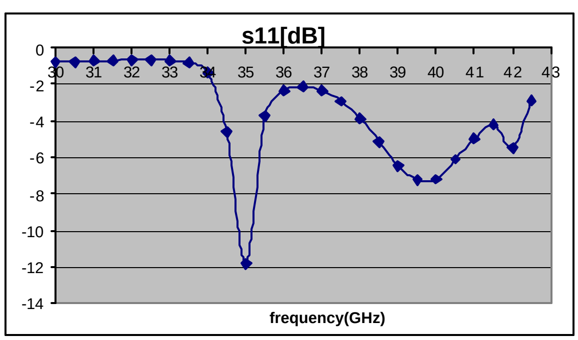


**Fig. 4 Simulated (MSTRIP40) input return loss for the return loss for the stacked patch antenna**