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# FDTD Model Performance Analysis for a Cavity Slot Antenna Array in a Variable Geometry Conformal Test Rig

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**Abstract**—In the pursuit of cost effective conformal antenna array design, an efficient and fast Finite-Difference Time Domain (FDTD) model is a highly desirable tool. This paper evaluates the performance of the University of Bristol Electrical Engineering Departments FDTD Model. The model is used to predict the antenna array patterns and inter element coupling for a variety of different antenna arrays in a variable geometry conformal antenna array test rig. A performance analysis and a comparison of measurements using the test rig with predictions using FDTD modelling is presented for the Cavity Slot Antenna Element.

## I. INTRODUCTION

The Finite-Difference Time Domain (FDTD) method has become well established since its inception 1966, [1]. This technique has been used in a wide range of applications, from modelling transmission lines and PCB to novel antenna designs. Despite the popularity of current FDTD techniques there is an increasing need for improved algorithms to support large scale conformal antenna array models with a minimum of computational resources. Previous work in this group has demonstrated a highly attractive, computationally efficient method to simulate such large arrays using a Time Domain Huygens approach [2].

## II. VARIABLE GEOMETRY CONFORMAL ARRAY TEST RIG

In order to investigate the performance characteristics of different antenna arrays over a range of radii of curvature, a consistent geometry between each element type is very important. To allow such comparisons, a Conformal Antenna Array Test Rig was produced, with mounting screws and laser etched alignment lines (Fig. 1). The use of laser cut transparent acrylic allows quick alignment of each element at the correct position and angle. Two antenna types were chosen initially, Conformal Cavity Slots (Fig. 2a), and Dual Feed Dual Circular Patch (Fig. 2b). The alignment markings allow five inter-element angle sets of 0, 5, 10, 15, 20 degrees corresponding to radii of curvature of Infinite, 0.46m, 0.23m, 0.15m, 0.11m. The test rig was designed to be mounted flush on an external ground plane on the Anechoic Chamber motorized antenna mount. The external ground plane was included to minimise

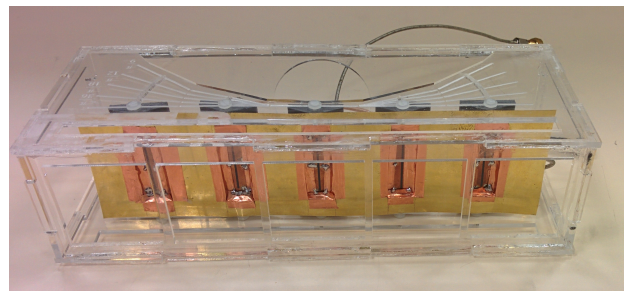


Fig. 1. Variable Geometry Conformal Antenna Array Test Rig, showing angle alignment markers and Cavity Slot Elements in Conformal Surface

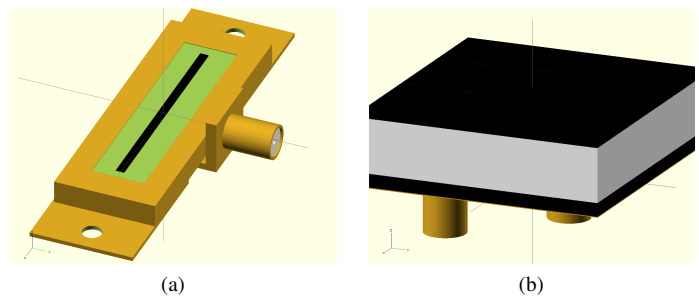


Fig. 2. Cavity Slot (a) and Dual Feed Dual Patch (b) Antenna Elements

the effect of the antenna mount on the array antenna patterns and to simplify FDTD modelling of the Test Rig.

## III. FDTD MODEL AND ANTENNAS

In order to efficiently model conformal antenna arrays at a variety of inter-element angles, a three stage method is used. This technique isolates each excited antenna in turn as a small high resolution model which is used to record “Huygen Snapshots” containing the surrounding electric and magnetic fields, and these snapshots are used to excite a large array model with a lower resolution FDTD mesh. In this second stage a frequency snapshot is recorded to allow the antenna pattern of each element in the array to be calculated, and a

second set of “Huygen Snapshots” are recorded for a third stage of small high resolution models to record the fields excited on each antenna element, allowing the calculation of inter-element coupling for the array.

This Three Stage Method has been used to support investigation into the performance a range of different antennas in Conformal Antenna Arrays. A Conformal Antenna Array Variable Geometry Test Rig, shown in Fig 1 has been produced to allow direct comparisons between the array performance for each different antenna type. Array measurements have been completed for two different antenna types, a Cavity Backed Slot antenna Fig 2a, and a Dual Feed Dual Circular Patch Antenna Fig. 2b. However the FDTD predictions for the Dual Patch antenna are not yet completed and so only the Cavity Slot Array will be considered.

This allows the correlation coefficients between modelled and measured array antenna patterns, and Scattering matrix data to be calculated, giving a statistical measure for the accuracy of this method.

#### IV. RESULTS

##### A. Array Pattern Comparison

There is good agreement between the modelled and measured antenna array patterns (0 degrees Fig. 3a, and 20 degrees Fig. 3b Total Power Pattern shown in x-y plane in line with the Test Rig Long axis). In order to numerically assess the FDTD model performance, the antenna array patterns are subjected to Pearson product-moment correlation analysis, showing only an average correlation of 12.7%.

##### B. Array Inter-Element Coupling

The performance analysis between measurements and predictions for S matrix terms gives some interesting results (Fig 4). All Scattering model and measured pairs have an average correlation of 54.41%. However upon closer inspection it is revealed that when separated into groups of inter-element coupling terms and element  $S_{1,1}$  terms, the  $S_{n=n}$  pairs all show a strong correlation with a mean of 88.47%.

#### V. CONCLUSION

An assessment of the difference in performance between the Cavity Slot Antenna Array Patterns and the Scattering matrix measurements and predictions suggests to the author that the Three stage method is accurately modelling the individual antenna elements, and it is the area between the elements and the flexible copper ground plane to which they are joined by copper tape and solder.

It is suggested that given a more consistent relationship between element and ground plane that might be more readily modelled the array patterns would show a much higher correlation with the measurements. Given that a conventional approach would have encountered the same difficulties, and incurred a much high cost in terms of computational time, this method has great potential to become a highly attractive tool for Conformal Antenna Array Design.

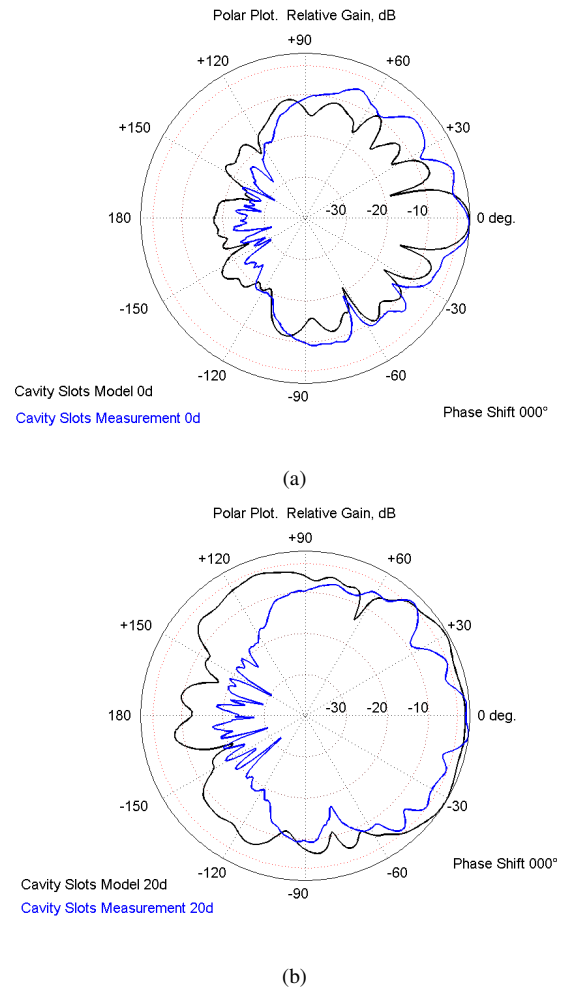


Fig. 3. Cavity Slot Pattern Comparison (0 degrees) (a) and Cavity Slot Pattern Comparison (20 degrees) (b)

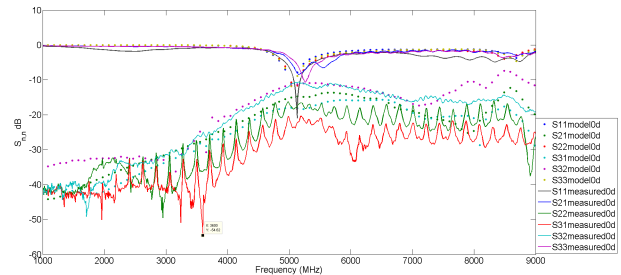


Fig. 4. Comparison of FDTD Predictions and  $S_{m,n}$  measurements

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