Investigation of various H-shaped antennas with an ATLM field-solver

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Abstract

In this contribution we investigate two variations of H-shaped planar antennas by using an ATLM field solver. The antennas are coupled in a different way to a microstrip feedline. The coupling is done alternatively by an aperture slot and a viahole. Using the ATLM method for antenna design, structures with finite metalization thickness and viaholes are modeled as easily as strictly planar structures. The calculated S-parameters of the antenna structures are compared to measured results.

Introduction

Planar antennas are mostly simulated by using the method of moments or the integral equation method. But the efficiency of these methods is restricted to the application on strictly planar structures. The effort of using these methods raises very high, when antenna structures have to be simulated, which contain structure details like viaholes or finite dielectric layers. The ATLM method is a fast electromagnetic field solver for field simulation in time domain [1]. This method is not restricted in its application to planar structures. Using properly matched absorbing boundary conditions we can use this method for the investigation of the near field properties of nearly arbitrary antenna structures. In this presentation we compare H-shaped antennas [2] of different coupling to a microstrip feedline by ATLM simulations.

The ATLM method

The three-dimensional TLM method with symmetrical condensed node (SCN) introduced by Johns [3] has proven to be a very powerful method of electromagnetic field computation [4]. In TLM, the space is discretized by introducing a mesh of transmission lines which are connected by nodes in each elementary cell. The electromagnetic field is represented by wave pulses scattered in the nodes and propagating in transmission lines between neighbouring nodes.

The network model of TLM has become useful in many applications, however it also results in nonphysical solutions which do not satisfy Maxwell's equations [5]. The presence of nonphysical or spurious solutions limits the applicability of the TLM method and indicates the use of unnecessary field variables. In fact, it as been shown that for the conventional three-dimensional TLM schemes, half of the field variables do not contribute to the calculation of physical solutions indicating the unnecessary use of half of the field variables.

In the alternating transmission line matrix (ATLM) scheme the TLM cells are subdivided into two subsets of mutually neighbouring cells [1,5]. Within each time step the state of one

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subset of cells is computed from the states of the neighbouring cells at the previous time step.

Since ATLM is based on the TLM scheme for the symmetrical condensed node (SCN), its field theoretical derivation is similar to the field theoretical derivation of the SCN. However, the sampling of the field components is different for the two TLM schemes: While for TLM with SCN, every three-dimensional cell with the spatial coordinates l, m, n is sampled at every time sampling point $k\Delta t$ in the cell boundaries, for ATLM, either the odd cells with odd $l + m + n + k$ or the even cells with even $l + m + n + k$ are sampled in the center of the three-dimensional cell. This sampling leads to a bijective one-to-one mapping between the six field components, six spatial derivatives of the field components and the twelve wave amplitudes.

Compared with existing TLM schemes the numerical effort as well as the storage requirements are reduced by up to 50% without loss of accuracy. Furthermore, spurious solutions occuring in existing TLM schemes can be avoided by ATLM. But like in TLM the structures are discretized into a mesh of transmission lines which yields a high flexibility for the application of structures with nearly arbitrary material and geometry. With that the ATLM method represents a flexible and efficient tool for the electromagnetic field simulation in time domain.

Simulation of H-shaped antennas

In this first investigation of antenna structures by using ATLM, the near field of the antennas is considered. The simulation of the fields in a wider area surrounding the antenna would require too much computation time and storage. The far field can be calculated in a second step by Fourier Transformation. The consideration of the near field in a local area by ATLM leads to useful results, when the absorbing boundary conditions of this area are choosen well.

We consider H-shaped antennas with different coupling to a microstrip feedline which are shown in fig. 1. The H-shaped antenna structure has especial advantegous properties due to its small size, which is only a quarter of the wavelength at the resonance frequency. The RT/duroid substrate has a relative dielectric constant of 10.8. For little variation of the resonance frequency the antenna can be shifted in the metallization plane.

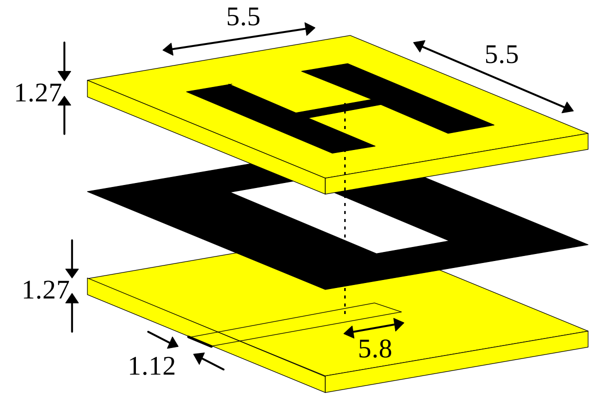

Fig.1: aperture-coupled H-shaped antenna (all structure sizes in mm)

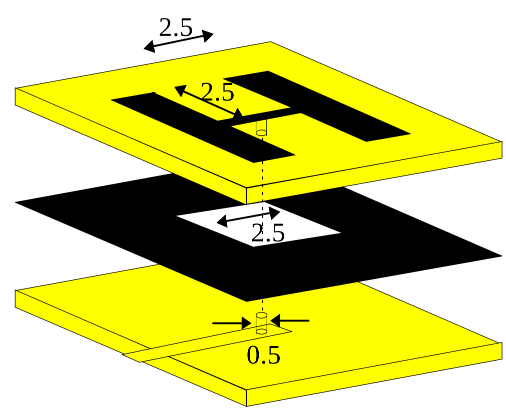

Fig.2: viahole-coupled H-shaped antenna

In fig. 1 the coupling is realized by an aperture which is a slot of the size 5.5mm $\times$2.5mm. This structure has also been investigated in ref. [2]. In fig. 2 the coupling is realized by a viahole. It is crossing an aperture of the size 5.5mm $\times$5.5mm. Due to the more direct coupling, the viahole structure promises better properties of the resonance of the antenna structure. On the other hand the technical realization of the viahole coupling requires a higher effort.

Results

In a first example we show the S-parameter of an aperture-coupled H-shaped antenna as can be seen in fig. 3. We see a well developped resonance with -23dB at the frequency of 4.6GHz.

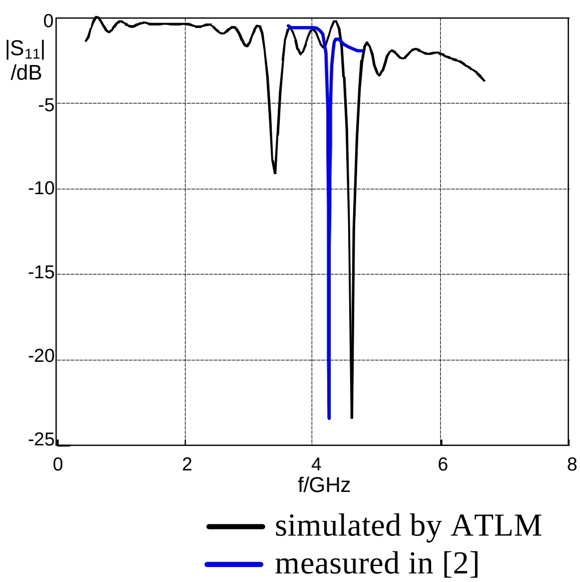

Fig. 3: absolute S-parameter value of the aperture-coupled H-shaped antenna

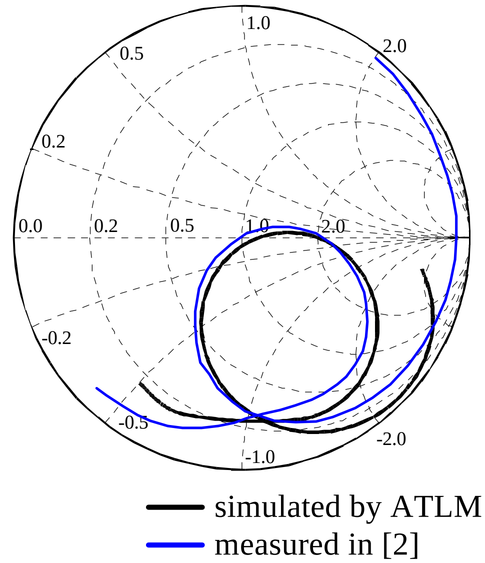

Fig. 4: S-parameter of the aperture-coupled H-shaped antenna

When we compare the calculated results to resonances of the measured results of ref.[2] which are at the frequency of 4.3 GHz we obtain an error of 6-7% in the resonance frequency. But for the estimation of the antenna properties the results proove to be sufficient. In the smith diagram of fig. 4 we see also a quite good agreement of the calculated resonance curve to the measured result.

The errors in the calculated results can be lowered by extending the region of the discretized space which is surrounded by absorbing boundaries. However the computation time for calculating the fields would raise by the exponent of three. This shows that it is very useful to combine a space discretizing method like the ATLM method for the near field modeling in nearly arbitrary structures with the efficient integral equation method for the far field description.

In a second excemple we consider the S-parameter of the viahole-coupled H-shaped antenna as shown in fig. 2. This excemple can not be calculated by the integral equation method without very high effort. The field modeling around the viahole requires a space discretizing scheme like the ATLM method.

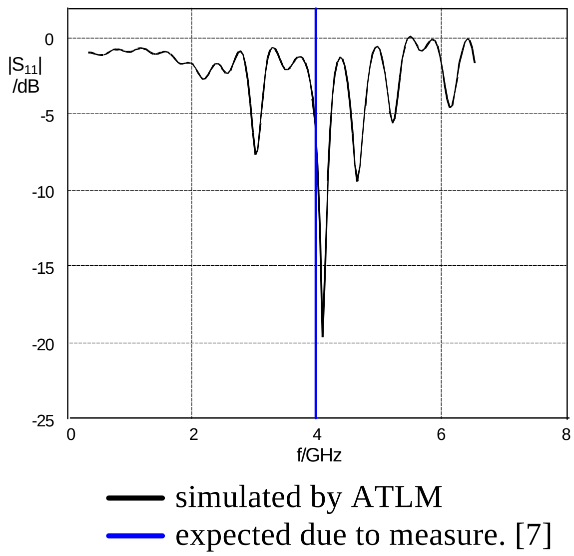

Fig. 5: absolute S-parameter value of the viahole-coupled H-shaped antenna

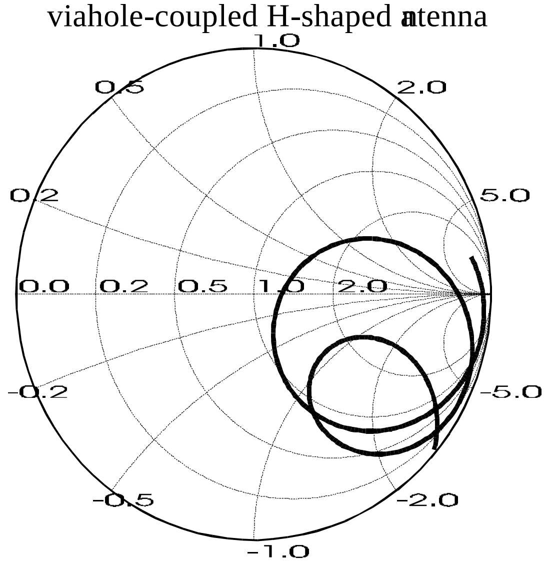

Fig. 6: S-parameter of the viahole-coupled H-shaped antenna

In fig. 5 we see several resonances in the case of the viahole coupled antenna. The main resonance frequency is shifted from 4.6 GHz to 4.1 GHz. Fig. 6 shows the resonance loops of the main resonance and the following resonance in a spectrum between 3.5-4.8 GHz. The new resonances are caused by the radiation of the viahole. This shows an advantage of the aperture coupled antenna. In ref. [7] a viahole coupled H-shaped antenna has been measured. The measurement shows that the size of the antenna is 24% of λ in the medium. With that we can expect from this measurement a frequency of 4.0 GHz for our antenna of the size 5.5. In fig. 5 we see a good agreement of the calculated resonance to the expected value.

Conclusion

We investigated H-shaped antennas with two variations of coupling, using the ATLM method. While the use of conventional methods for the simulation of antenna structures like the method of moments or the integral equation method leads to difficulties in the case of structures with viaholes and finite dielectric layers the ATLM method is not restricted to structures of special type. With this the method could be used also for the viahole coupling of antennas which is compared to the aperture coupling in this contribution. The near field properties of the different antenna structures were compared to those of measured results. There is a quite good agreement of the results but the description of the far field around the antenna leads to a high computation effort. So the results show that it is useful to combine a flexible space discretizing method like the ATLM method for the near field modeling with the efficient integral equation method for the far field description.

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