A Novel Multilayered Planar Antenna for Ultra Wide Band (UWB) Intelligent Antenna Systems

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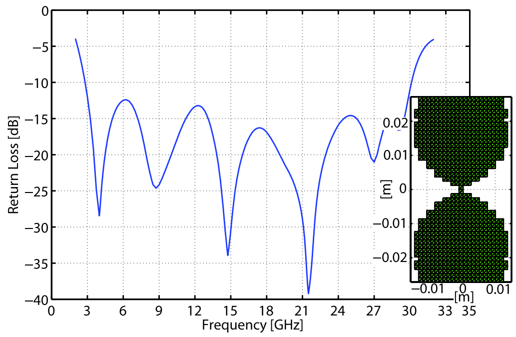
Abstract

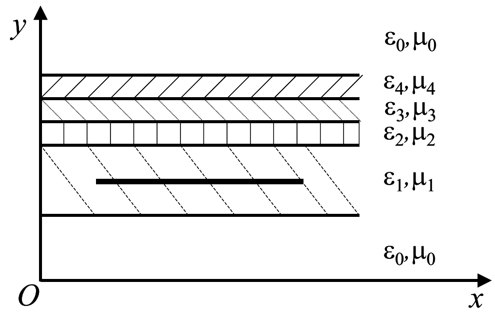
We present a novel planar multilayered antenna for UWB intelligent antenna systems applications. An UWB radiating element with an impedance bandwidth from $3 - 26$ GHz is designed using a genetic algorithm (GA) in connection with method of moments (MoM). To achieve compact size and unidirectional radiation characteristics the antenna is embedded into a dielectric substrate-superstrates multilayered structure. We show that the substrate-superstrates configuration maintains the impedance with a little frequency dependence from $3 - 26$ GHz while unidirectional radiation characteristics can be achieved. The space filtering properties of the antenna are also investigated. To validate the numerical results we compare the computations with an other commercial CAD.

Introduction

In recent years, considerable research in communication and microwave engineering has been devoted to the development (UWB) systems and technology [1], [3]. This technology is expected to offer high data rates over short distances without suffering from the multi-path interferences [4]. Among many others possible applications, UWB antennas are also used in high resolution radar imaging, for secure transmissions in multi-user network applications [5]. Although digital signal processing for intelligent antennas is feasible for ultra wide frequency bands of operation, the real limitation of the system originates form the antenna itself [5]. There are several issues to be considered in designing intelligent UWB systems. In particular also in the most general case of non-line-of-sight propagation an antenna with high directivity allows space division multiplex transmission [2]. This yields to challenging specification requirements for the antenna design like a frequency independent phase center, frequency independent radiation pattern and large impedance bandwidth. Popular broadband antenna structures like bow-tie, vivaldi, TEM horn, etc., cannot fulfill all those requirements [3]. In this work, a novel antenna for intelligent UWB system applications is presented. Due to the small size requirement, the antenna geometry of the UWB radiating element is chosen to be planar. The synthesis and the optimization of the radiating element is done using genetic algorithm (GA) in connection with method of moments (MoM). To achieve the required unidirectional characteristics the radiating element is embedded into a substrate-superstrates structure. The impedance bandwidth of this antenna is $3 - 26$ GHz. The phase center of the antenna is investigated on the basis of a frequency domain directional antenna transfer function [2] for different elevation angles.



(a) Best generated structure and its return loss.

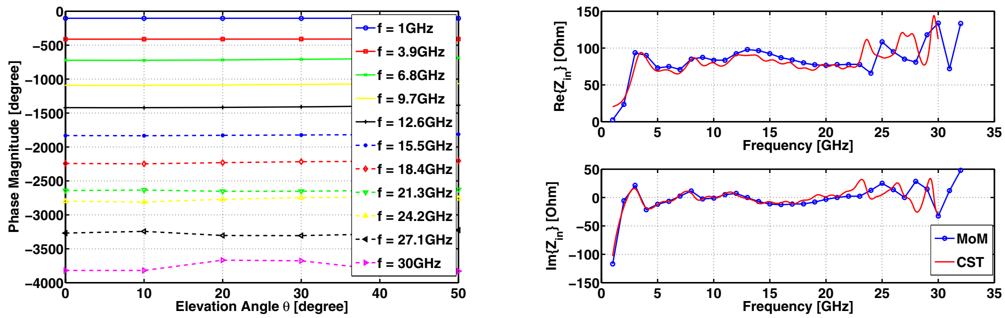


(b) The substrate-superstrates configuration.

Figure 1: Element geometry (a), Layered structure (b), Return loss (a).

Radiating Element Synthesis

In the synthesis of the radiating element the electromagnetic problem is solved by means of the electric field integral equation (EFIE). To solve the integral equation we use MoM expanding the current into a series of Rao Glisson Wilson vector basis functions (RWG) [6]. Since the RWG basis functions are supported by a triangular mesh, the surfaces S' of the radiating elements will be meshed by triangles. To synthesize and optimize the UWB radiating element we used genetic algorithms [9]. The RWG basis function are described by a pair of triangles that form one rectangular cell. The bit combinations defining the meshing cells of the antenna geometry element play the role of the "genes". The combinations of genes form chromosomes which give the complete bits representation of the antenna geometry. The genetic algorithm optimizes the antenna geometry to reach the required antenna specifications. The genetic process starts with the initialization of random chromosomes. In the first step we impose general optimization limits to the antenna geometry. Considering the symmetry of the structure, the number of parameters to be optimized is reduced by a factor of two. Before running the genetic algorithm the population number and the number of iterations must be chosen. The population number (N_{pop}), i.e., the maximum number of structures that may be considered, is set to $N_{pop} = 16$. We note that a pure random search would lead to $12^{21} = 4.6 \times 10^{22}$ possible structures. The number of iteration is 40. The mutation per iteration is set to 10% of the total bits in all chromosomes (population). Random single point crossover is used to mate the selected parents. The selection strategy for parents is based on proportionate selection (roulette-wheel selection). In this way the probability of each chromosome to be selected is proportional to its score value. The scoring scheme is chosen to maximize the antenna return loss. As score the negative logarithmic return loss weighted and averaged over the considered frequency interval is used. To higher scores a low probability to be chosen as a parent is assigned. According to this criterion, the solution by the GA is guided converge towards structures that have return loss below -12 dB or -15 dB or -20 dB in the frequency range of $3 - 26$ GHz. In Fig. 1(a) shows the geometry of the optimum generated structure and the computed return loss.



(a) (b)

Figure 2: Phase (a). Impedance (b)

Substrate-Superstrates configuration

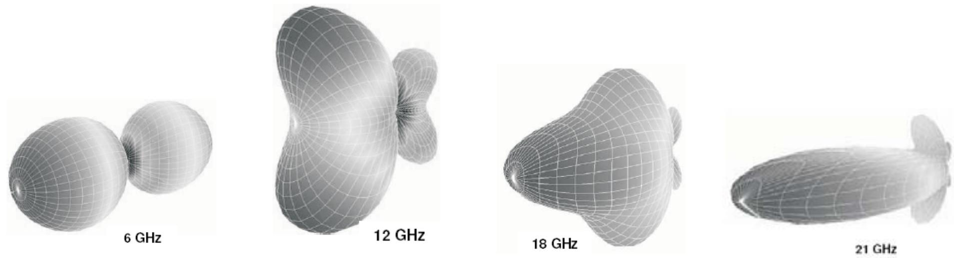
For applications in UWB antenna arrays, the antenna elements should exhibit a unidirectional radiation pattern. Choosing properly the value of the permittivity and the thicknesses of the dielectric layers one can enhance gain and improve radiation efficiency [7]. To achieve a unidirectional radiation pattern, we place the radiating element in the middle of a substrate of dielectric constant $\varepsilon_1 = 2.2$. Additional superstrates with superstrates $\varepsilon_2 = 75$, $\varepsilon_3 = 25$ and $\varepsilon_4 = 9$, respectively are used to maximize the radiation efficiency on the upper half-plane, Fig. 1(b). Their thickness are chosen in a way to minimize the propagation of surface waves. The overall behavior of the surface waves is similar to the single layer case. The lower dominant mode is the TM_1 which above cut-off independently to the substrate thickness. The next excited modes are the TE_1 and TM_2 [7].

Results and Validation

The antenna is investigated numerically by computing the input impendence, the radiation pattern and the phase center. The input impedance is computed by MoM and the results have been compared with these obtained with CST Microwave Studio. In Fig. 2(b), we can see that the real and the imaginary part of the input impedance are centered around 80 Ω and 0 Ω respectively within a frequency band of $3 - 26$ GHz. A good agreement of the results obtained with both methods is observed. The stability of the phase center is investigate by means of directional transfer functions [2]. A directional transfer function is defined for different elevation angles θ, Fig. 2(a). The phase is reported as function of θ and the frequency and a good linear behavior can be observed until approximately 25 GHz. Fig. 3 shows a 3D view of the antenna radiation pattern that tends to have unidirectional radiation characteristic at intermediate and high frequencies.

Conclusions

A novel planar multilayered antenna for UWB intelligent antenna systems has been presented. The planar UWB radiating element has been design by the combination



(a) Radiation pattern at 6 GHz. (b) Radiation pattern at 12 GHz. (c) Radiation pattern at 18 GHz. (d) Radiation pattern at 21 GHz.

Figure 3: View of the radiation pattern as function of the frequency is shown.

of genetic algorithm and integral equation method. We have shown that a UWB antenna element embedded in a dielectric substrate-superstrates structure exhibits impedance bandwidth, unidirectional radiation characteristics and constant phase center up to 25 GHz.

Acknowledgment

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