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MIMO Antenna System Using Orthogonally Polarized Ultra Wide Band Antennas With Metamaterial

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Abstract

Modern wireless communications require wide band width resulting in an increased demand for Ultra-Wide Bandwidth antennas. This paper proposes a design for a compact, ultra wide bandwidth antenna with metamaterial. It will be small in size and utilize the best performance of spaced array with a good correlation between the antennas. The antennas are designed with metamaterial structures embedded in substrate. Using the size reduction of double the existing type of antennas, the proposed model exhibits the best in radiation bandwidth, mutual coupling, radiation pattern, return losses, cover UWB frequency range very well in (3.1-10.6)GHz and polarization with a good Isolation of more than 22dB .

Keywords: metamaterial, MIMO, compact antennas.

منظومة الهوائيات متعددة المداخل والمخارج التي تستخدم الهوائيات عريضة الحزمه المتعامده استقطابيا مع المواد ذات معامل الانكسار السالب

الخلاصة

تتطلب الاتصالات الحديثة حزمة عريضة من الترددات مما ادى بالنتيجة الى زيادة الاعتماد على الهوائيات ذات الحزم الترددية العريضة. في هذا البحث تم اقتراح التصميم للهوائيات عريضة التردد ذات الحجوم الصغيرة مع استخدام مواد ذات معامل الانكسار السالب. وهذه الهوائيات صغيرة الحجم و تقدم اداء افضل للفواصل بين الهوائيات و فوارق طورية كبيرة بين مجموعة الهوائيات . تم تصميم الهوائيات مع مواد ذات معامل الانكسار السالب التي اضيفت الى المواد العازلة المرافقة للهوائيات . ثم تقليل الحجم مرتين اقل مقارنه مع الهوائيات الموجودة . والنموذج المقترح له اداء افضل في عرض الاشعاع والعمل المترابط بين الهوائيات ونموذج الاشعاع و فواقد الارجاع وتغطية المجال الترددي العريض (3.1 - 10.6) كيكا هيرتز و الاستقطاب مع عزل جيد اكثر من 22 ديسبل.

1. Introduction

Ultra Wideband (UWB) is a promising communication technology for short-range communication scenarios. It is a low-power, high data rate technology. It is used in WBAN and mobile communication systems [1], and they have great resistant to other system̓s interference or noise [2].

Over 30 years ago, Veselago postulated a homogeneous isotropic

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electromagnetic material in which both permittivity and permeability were assumed to have negative real values. He studied uniform plane-wave propagation in such a materials [3].In these metamaterials (MTM), the direction of the Poynting vector of a monochromatic plane wave was opposite to that of its phase velocity. Veselago suggested that this isotropic medium supports backward-wave propagation and its refractive index can be regarded as negative.

These materials have drawn a lot of interest in the antenna community due to their promising features. Recently, metamaterials have been extensively applied for antenna applications to achieve antenna miniaturization, improved directivity, beam scanning, and beam width control [4].Metamaterials (MTM) can exhibit a negative refractive

Index with permittivity ε and permeability μ being simultaneously negative.

MTM can be structured and manufactured to exhibit electromagnetic properties that are tailored for specific applications. Small antennas are one of most important application of MTM. An electrically large, but physically small antenna can be designed by using MTM while maintaining the same or better performance than conventional ultra wide band (UWB) antennas.

Ultra wide band (UWB) communication systems have an unprecedented opportunity to impact communication systems. The enormous bandwidths available to them, the wide scope of the data rate/range tradeoff, and the potential for very low cost operation leading to pervasive usage. This presents a unique opportunity for UWB to impact the way people interact using communication systems.

Why do we use UWB. First the enormous bandwidth capabilities of UWB could potentially offer data rates measured in Gbps. Second, the bandwidth is overlaid on many existing allocations, which is of great concern for those groups with primary allocations [6]. Impulse radio communication systems utilize very short pulses in transmission that results in a UWB. The UWB signal is noise-like which makes interception and detection quite difficult. Due to the low spectral density, UWB signals cause very little interference with existing narrow band systems. Multiple-input and multiple output (MIMO) systems transmit two or more data streams in the same channel at the same time, using multi-antennas, thus achieving high throughput without consuming extra radio frequency and high link reliability of wireless communication. MIMO systems are expected to be next generation wireless service. Today they are used in specific applications such as IEEE802.16e, and IEEE 802.11n. This system uses a plurality of antenna elements to enhance channel capacity in multipath conditions, wherein each multipath route can be treated as a separate channel by occupying the same frequency band. It is critical to arrange compact antenna elements without impairing antenna performance and system requirements. Mutual coupling and isolation between adjacent antennas is key to achieve the highest antenna performance in MIMO antenna configuration.

For low mutual coupling, antennas must be far away each other. As the distance between two antennas is decreased, the mutual coupling is increased and the radiation efficiency of each antenna is rapidly degraded. To overcome the limited antenna space (distance) between two antennas , and to enhance the characteristic of the antenna array in modern communication systems the design of antenna array use small antennas with metamaterial to reduce the size and return loss. My research shows a design of orthogonally Polarized UWB using smaller antennas (twice as small as current antennas)[2] with metamaterial structures embedded in the substrate, compared to existing antennas[2].This proposed model shows improvements in radiation bandwidth, return loss, radiation pattern and polarization difference between two antennas.

In this paper II will propose an antenna array design to work as orthogonally polarized UWB aperture antennas, III propose a Metamaterial design to use with antenna elements, and IV show the analysis of using MTM with such antennas to minimize the size and enhance the performance of antenna array.

2. Antenna Design And Performance

Aperture antennas backed are designed by using a ground plane and built with MTM on substrate FR408 from Isola Company with (μ=4.4 ,ε=4).The two orthogonally polarized antennas are fed by strip for each aperture ,the antennas are placed perpendicular to one another. The radius of the aperture of each antenna is 12mm, two times less than antennas in [2] but the results achieved in this work show that radiation patterns are better for communication systems.

The proposed antenna geometry has two circular aperture antennas with strip line for feed, backed by a ground plane that extends from both sides and one that built on the metamaterial substrate (**Fig.1**). The strip lines are connected with two SMA connectors are soldered to the strip lines and used as inputs. The two perpendicular apertures work in orthogonally polarized MIMO and the results show a good isolation between channels with maintaining a low profile. The element feed profiles have been optimized in order to achieve the best adaptation possible in the 3.1-10.6GHz frequency band by using **Ansoft High Frequency Structure Simulator (HFSS) ver.12.0[7]** for the antennas(**Fig.2)**

3. Metamaterial Design

Previous researchers have developed means of achieving magnetism from passively embedded circuits (EC) conductors. This study builds upon their existing designs. One of our previous designs consisted of a single split ring with an integrated capacitor, providing a lumped-element capacitance performance (**Fig.3**). During the design and simulation of MTM unit cell, I used the design method and the equations which are used in ANSOFT Left-Handed Metamaterial Design Guide[8], and I tested a Split Ring Resonator, Square LC Resonator, and Omega Medium Resonator, which are shown in (**Fig.3**). One drawback of the square LC resonator is its non-optimal use of unit cell area. A good design for optimal magnetic permeability would enclose as much of the unit-cell area as possible. This would achieve the highest coupling of incident magnetic energy while maximizing packing density[9].A square inductive resonators(**Fig.2**and **Fig.3**) seems to be a reasonable candidate and was the option used in previous design. We have since concluded that spiral loop is preferable because it uses less area and provides equivalent capacitance while simultaneously providing additional inductance and additional permeability, and has better $\mathbf{S_{11}}$ and $\mathbf{S_{21}}$ parameters than the other structures .The unit-cell of MTM design performed and tested by using Ansoft Designer (Method of Moments) and HFSS (Finite Element Method) [7], were fabricated using milling machine at the University of North Texas (UNT).

4. Analysis of Antenna With Mtm

The proposed antenna with unit cell of MTM was analyzed by comparing it with the radiation patterns without MTM. The antennas had a similar structure so the analysis will be for one antenna. Several variations in the design were simulated before achieving the design shape of the antennas. Upon simulating the antenna design, the simulation results showed a broad but discontinuous band width with high S_{11} values in certain parts of the band (**Fig.4**). Upon achieving the best possible results from this approach, the metamaterials technology were used to further improve the bandwidth and enhance the antenna array performance **(Fig.5).**

Measured S_{11} parameter of the antenna shown in Fig.6

. In order to achieve an antenna with the best parameters, the dimensions of the spiral and substrate must be controlled by tuning the dimensions of the spiral and the thickness of substrate during the simulation. $\mathbf{S}_{12}$, **S21**, and $\mathbf{S}_{22}$ Parameters of proposed antenna with MTM were measured by using ROHDE&SCHWARZ Vector Network Analyzer ZVB20 (**Fig.7**). These S_{12} and S_{21} are equal, thus they are seen as one color

The radiation patterns of the proposed antennas were then measured and studied in detail. This included a study of co-and cross-polarization performances for E and H planes using Antenna Measurement Studio 5.9 from Diamond Measurement Systems (**Fig.8** and **Fig.9**).A picture of the antenna array mounted on the Antenna Measurement Studio 5.9forthe radiation pattern measurements is shown in (**Fig.8**). **Fig.9** displays copular and cross-polar radiation pattern measurements for 4GHz and 9GHz in E and H planes.

The simulations and measurements show that the proposed antennas provided low return losses covering UWB frequency range, enhance the performance of the optimized adaptation for MIMO two orthogonally polarized UWB antennas with low mutual coupling between the two types of polarization with a good Isolation of more than 22dB.

5. Conclusion

This paper has presented the design of two compact UWB antennas using MTM technology which consist of periodically repeated square loop resonators. Both antennas are smaller than conventional UWB antennas. The simulations and measurements are in good agreement, and show that the proposed antennas provide low return losses cover UWB frequency range very well, enhance the performance of the optimized adaptation for MIMO two orthogonally polarized UWB antennas with low mutual coupling between the two types of polarization with a good Isolation of more than 22dB.Proposed antennas cover the UWB (3.1-10.6) GHz with better S Parameters (S_{11}, S_{21}, and S_{22}) comparing with the work of the antennas without metamaterial.

MIMO structure in antennas can be used in base stations for mobile communication because the radiation is directed forward and only covers 120^0[10].The advantages of the proposed antennas make this array a suitable model for wide band array with dual polarization MIMO systems which can be used in communication networks.

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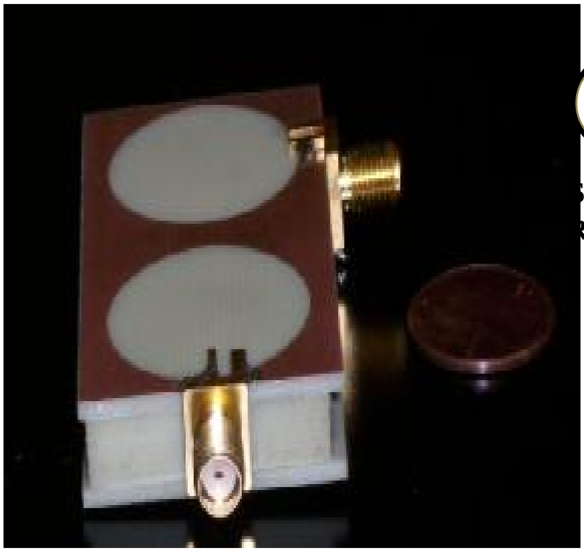

Figure.1. The structural details of the antennas prototype

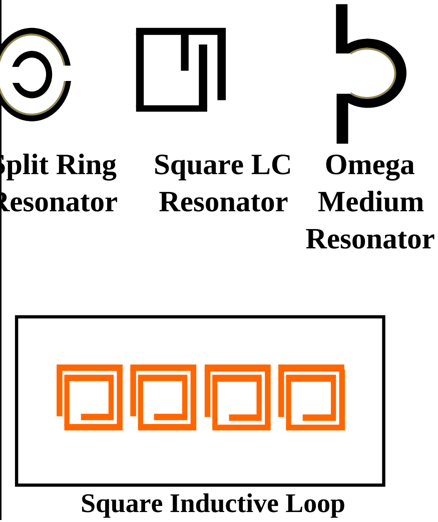

Figure3. Different Types of Resonators of MTM

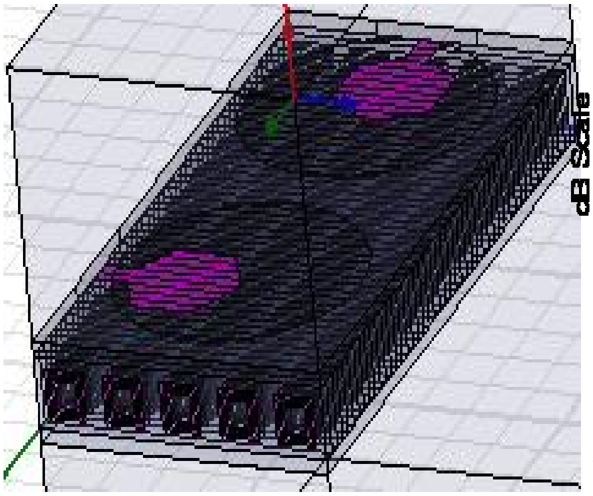

Figure.2. The schematic of antennas built on met material

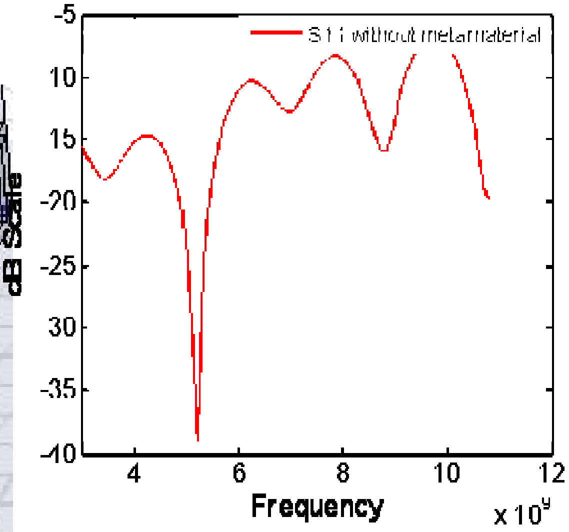

Figure.4. Simulated S_{11} Parameter without MTM

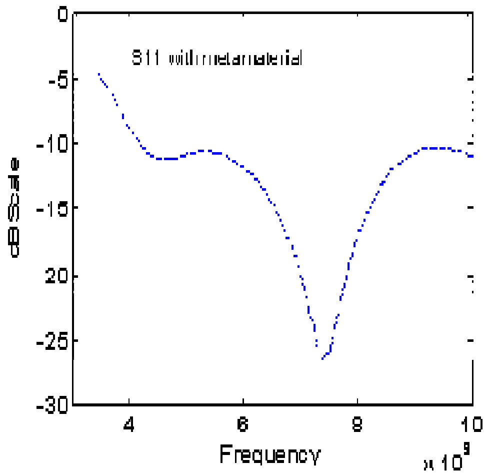

Figure.5. Simulated S_{11}Parameter of antenna with MTM

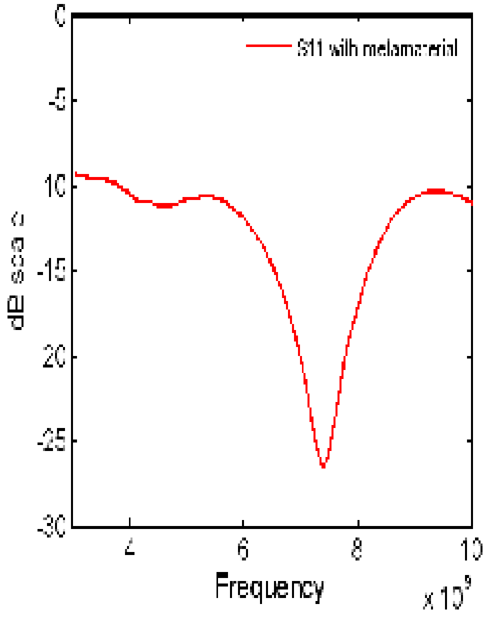

Figure.6. Measured S_{11} parameter of the antenna

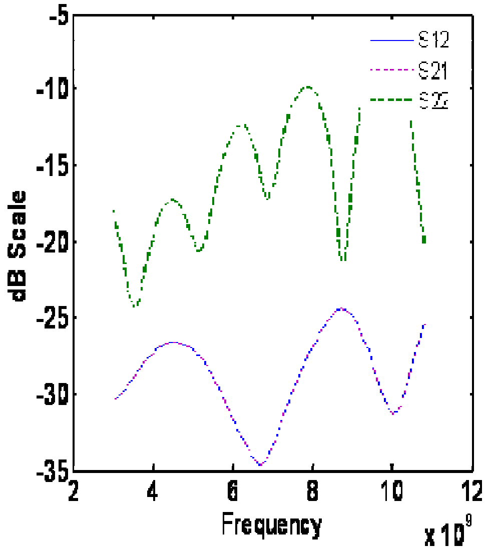

Figure.7. S_{12} and S_{22} of the proposed antennas

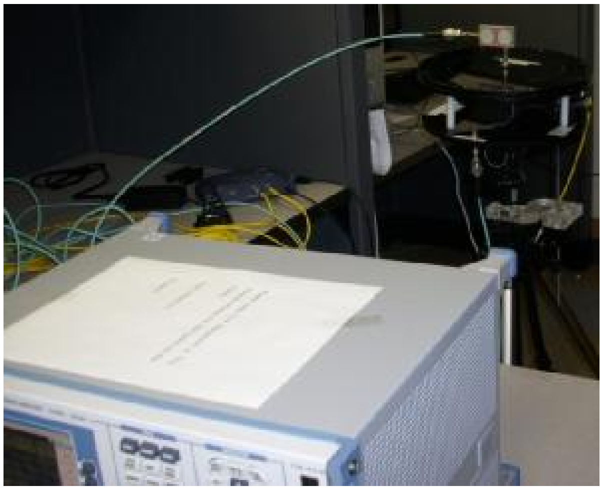

Figure.8. A picture of the antenna array mounted on the Antenna Measurement Studio 5.9

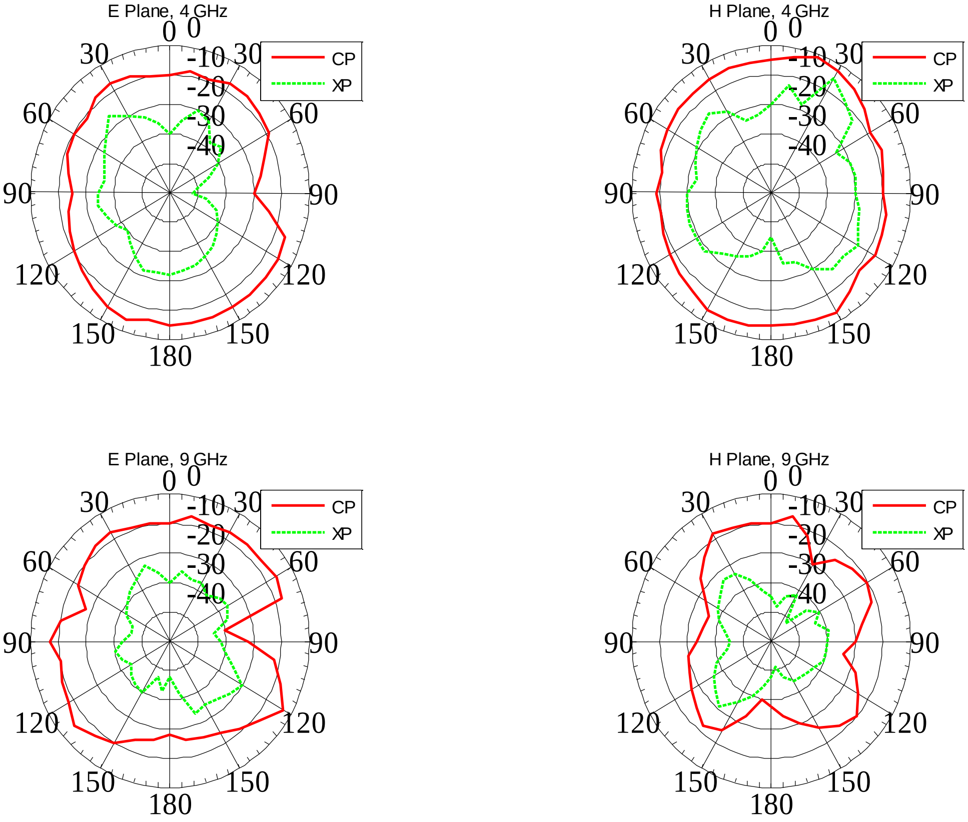

Figure.9 Radiation pattern of the antennas in 4GHz and 9GHz