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A UWB Multiple-Input Multiple-Output Reconfigurable Antenna

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Abstract— An ultra-wideband (UWB) multiple-input multiple-output (MIMO) antenna that is programmable is shown in this work. The frequency range covered by the described antenna is 11:1 from 440 MHz to 5 GHz. while maintaining a small footprint for MIMO applications. By combining a UWB monopole antenna with a tunable matching network via two distinct signal routes from a single feed point, the ultrawideband functionality is achieved. The UWB antenna functions across the remaining frequency range, whereas the adjustable part spans the 440 MHz to 700 MHz range. Orthogonally positioning two identical UWB antennas on the same substrate allows for the construction of a MIMO configuration and polarization diversity. The presentation of MIMO diversity parameters and the reflection coefficient for the complete operation region is made.

Keywords— Reconfigurable antenna, MIMO, and small UWB.

I. INTRODUCTION

Wireless data traffic reached 13.7 trillion MB in 2016, and between 2015 and 2016 there was a 238 percent growth in data usage. [1]. Ultra-wide band (UWB) technologies have been introduced to meet the ever-increasing enormous data traffic and high data demand. UWB technology experiences multipath fading, just like the majority of other wireless systems, despite being able to reach faster data speeds with less power. Multiple-input multiple-output (MIMO) systems, on the other hand, can boost channel capacity and lessen multipath fading. The correlation between the signals received by each of the antenna elements in use determines how well a MIMO system performs. Using many antennas in a small area can result in significant coupling and reduce the system's overall performance. Consequently, compactness, high isolation, and low correlation are very this paper presents a tiny reconfigurable UWB MIMO antenna. First, a UWB antenna that can be reconfigured is created. It is then employed in the building of a MIMO antenna system.

Simulation results are used to calculate MIMO diversity performance.

Due to the constantly growing demand for new wireless services, the bulk of the RF spectrum is already occupied by numerous users through various wireless and radar standards. applications. In addition to the well-known scarcity of spectrum, utilization of the spectrum is not evenly distributed, resulting in certain communication spectra being more crowded than others [5]. Cognitive radio, which is aware of its surroundings and able to modify its operating frequency band for dependable communications, is required to address this wasteful spectrum consumption and possibly even overcome the crowded spectrum [6]–[7]. Wideband antennas that are capable of functioning at any accessible spectrum are so appealing.

Resonant antennas, which typically operate at a set frequency with a restricted bandwidth, make up the majority of antennas used in modern wireless systems, such as cellular networks. As a result, they are unsuitable for implementing a strong cognitive radio that has a very broad operational bandwidth. However, while non-resonant traveling-wave antennas (such as horn and log periodic antennas) are good for wideband operations, their diameters make them unsuitable for mobile applications because they are significantly larger than resonant antennas. This work proposes a small, broadband, reconfigurable antenna that can be used for mobile devices. It can operate in the 400 MHz to 4 GHz radio frequency spectrum. The idea behind the creation of the The revolutionary combination of a tunable matching network (which covers the lower band) and a UWB planar monopole (which covers the upper band) is the basis of the proposed antenna. An antenna prototype is created, tested, and assembled. Proof-of-concept has been effectively shown.

An antenna that can dynamically change its frequency and radiation characteristics in a controlled and reversible way is called reconfigurable. Recognizable antennas incorporate an internal mechanism (such as varactors, RF switches, mechanical actuators, or tunable materials) that allows the deliberate redistribution of the RF currents over the antenna surface and produces reversible modifications of its properties in order to provide a dynamic response. Because the reconfiguration mechanism is inside to the antenna rather than external to an external beamforming network, reconfigurable antennas are different from smart antennas. Reconfigurable antennas can be reconfigured to meet changing operating needs or to optimize antenna performance under varying conditions.

In order to maximize connectivity, wireless communications have advanced to the point where several radios must be integrated into a single platform. This paper discusses the reconfigurable antenna design method. It is suggested to use reconfigurable antennas to accommodate various wireless services that operate across a broad frequency range. When it comes to meeting new system requirements, they exhibit great promise. They demonstrate the capacity to alter their behaviors and geometries in response to environmental changes. The throughput of reconfigurable antennas is comparable to that of a multiantenna system. They employ single-antenna geometry that is dynamically flexible and adaptive without requiring more space than is needed to support numerous antennas. The design and operation of reconfigurable antennas are optimized by eliminating superfluous redundant switches in order to reduce biasing problems and enhance system performance.

A. Antenna reconfiguration types

Reconfigurable antennas can be classified according to the antenna parameter that is dynamically adjusted, typically the frequency of operation, radiation pattern or polarization.

a. Reconfiguring frequencies: -

The frequency of operation of frequency reconfigurable antennas can be dynamically changed. They are especially helpful when various communications systems converge since a single reconfigurable antenna can take the place of several necessary antennas. RF-switches, impedance loading, or tunable materials are commonly used to physically or electrically modify the antenna dimensions in order to reconfigure its frequency.

b. Reconfiguration of the radiation pattern:

The deliberate alteration of the radiation pattern's spherical distribution is the foundation of radiation pattern reconfigurability. The most extensive use is beam steering, which involves directing the direction of greatest radiation to increase antenna gain when connecting to mobile devices. Typically, switchable and reactively-loaded parasitic elements or movable/rotatable structures are used in the construction of pattern reconfigurable antennas. Reconfigurable antennas based on metamaterials have garnered interest in the past ten years because of its wireless applications, compact form factor, and broad beam steering range. As an alternative with tunable directivities, plasma antennas have also been studied.

c. Reorganizing polarization:

Antennas with reconfigurable polarization can flip between various polarization modes. Reduced polarization mismatch losses in portable devices can be achieved by utilizing the capacity to flip between horizontal, vertical, and circular polarizations. A multimode structure's polarization reconfigurability can be achieved by adjusting the multimode structure's mode balance.

d. Rearranging compounds:

The capacity to simultaneously adjust many antenna parameters, such as radiation pattern and frequency, is known as compound reconfiguration. The most popular use of compound reconfiguration is when beam-scanning and frequency agility are combined to increase spectral efficiency. Compound reconfigurability can be attained by dynamically redesigning a pixel surface or by combining several single-parameter reconfiguration techniques inside the same structure.

II. ADAPTABLE UWB MIMO ANTENNA TECHNIQUE

The reconfigurable UWB antenna operates on the same basis as the work described in [2]. Two distinct routes are created when the discrete switch (PE42422) is linked to the UWB antenna, which operates in the 1–5 GHz frequency band. These two paths are combined with a second switch to create a single path.

A. Techniques for reconfiguration: -

There are various kinds of antenna reconfiguration methods. They are primarily electrical (using varactors, PIN diodes, or RF-MEMS, for example), optical, physical (mostly mechanical), and material-based. Materials for reconfiguration processes may include liquid crystals, solids, or liquids (such as liquid metal or dielectric liquid).

a. Radio-frequency microelectromechanical system:

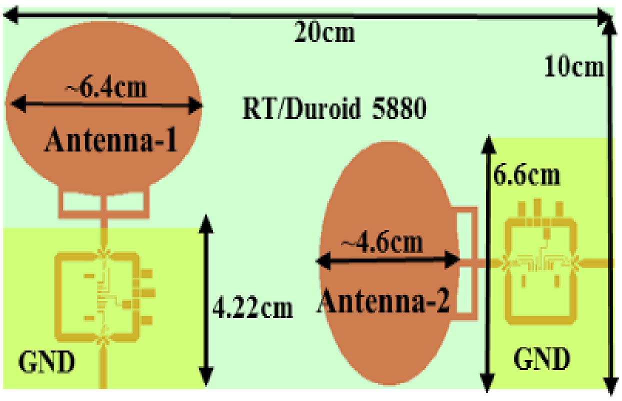
A microelectromechanical system having electronic components made up of moving sub-millimeter-sized pieces that have radio-frequency (RF) capabilities is known as a radio-frequency microelectromechanical system, or RF MEMS.[1] Many RF technologies can be used to implement RF functionality. In addition to RF MEMS technology, the RF designer can also utilize vacuum tube, ferrite, ferroelectric, silicon-based semiconductor (RF CMOS, SiC, and SiGe), and III-V compound semiconductor (GaAs, GaN, InP, and InSb). Cost, frequency, gain, large-scale integration, longevity, linearity, noise figure, packaging, power handling, power consumption, dependability, ruggedness, size, supply voltage, switching time, and weight are all trade-offs that each RF technology offers.

b. PIN diode:

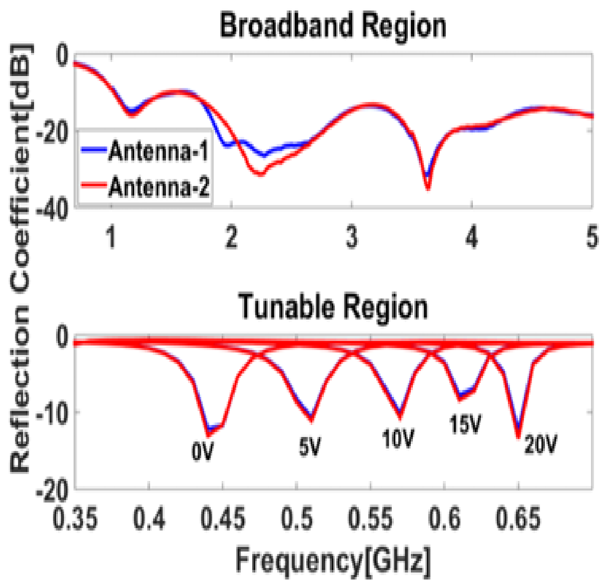
A diode with a broad, undoped intrinsic semiconductor region sandwiched between an n-type and p-type semiconductor region is known as a PIN diode. Since the p-type and n-type regions are utilized for ohmic connections, they are usually extensively doped. An conventional p-n diode is not like the wide intrinsic area. Although the PIN diode's vast intrinsic area renders it less effective as a rectifier—one of a diode's common uses—it is nevertheless a good fit for high-voltage power electronics applications, rapid switches, attenuators, and photodetectors. It was in 1950 that Jun-Ichi Nishizawa and associates devised the PIN photodiode. This gadget uses semiconductors.

c. Varicap/ Varactor diode:

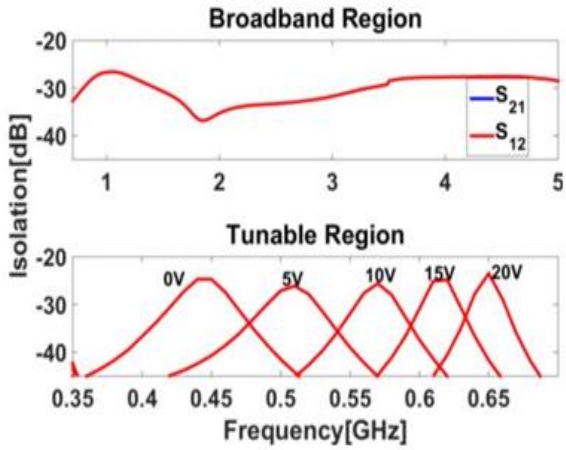
A diode type called a varicap, varactor, variable capacitance, variable reactance, or tuning diode is made to take use of a reverse-biased p–n junction's voltage-dependent capacitance. Varactors are not subjected to DC current flow since they are operated in a reverse-biased mode. The varactor's junction capacitance is determined by the thickness of the depletion zone and the amount of reverse bias. Doping profile affects the characteristic of capacitance change. In the case of an abrupt junction profile, capacitance is inversely proportional to the thickness of the depletion zone, and the thickness of the depletion region is proportional to the square root of the applied voltage. Therefore, the square root of the applied voltage and the capacitance have an inverse relationship. Although hyperabrupt varicaps have a higher capacitance variation and can operate at lower voltages, the capacitance change for hyperabrupt junction profiles is more non-linear. Variable junction capacitance is a feature of all diodes; however, varactors are designed to take use of this property and maximize the fluctuation in capacitance. An illustration of a varactor cross section with a p–n junction-based depletion layer is shown in the image. A Schottky diode or a MOS can also be used to create this depletion layer. Regarding CMOS and MMIC technology, this is significant.



(a)



(b)



(c)

Figure 1. (a) shows the schematic of an e-configurable UWB MIMO antenna; (b) simulates the broadband and tunable operation region's reflection coefficient; and (c) simulates the isolation of the tunable and broadband operating regions. port for input and output.

One of the pathways uses a tunable matching network, and the varactor-tuned (SMV2203-40LF) matching circuit is made to match the antenna to 50 Ohms.

The A UWB Multiple-Input Multiple-Output Reconfigurable Antenna has been designed using the following relation as

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \varepsilon_r F\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]}\right\}^{1/2}} \quad (1)$$

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Where $F = \frac{8.791 \times 10^9}{f_r \sqrt{\varepsilon_r}}$

The equations used to calculate the widths of the micro strip feed line are shown below

$$Z_0 = \frac{\eta_0}{2\pi\sqrt{\varepsilon_{re}}} \ln\left\{\frac{F_1}{u} + \sqrt{1 + 4/u^2}\right\} \quad (2)$$

Where

$F_1 = 6 + (2\pi - 6) \times exp\{-(30.666/u)^{0.7528}$

$\eta_0 = 120\pi\Omega$

$u = W/h$ and

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{10}{u}\right)^{-ab} \quad (3)$$

$$b = 0.564\left(\frac{\varepsilon_r - 0.9}{\varepsilon_r + 0.3}\right)^{0.053}$$

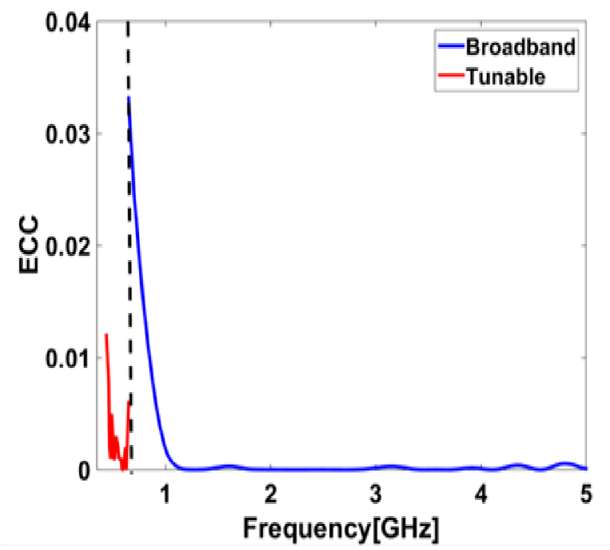
$$\frac{W}{h} = \frac{2}{\pi}\left\{B - 1 - ln(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[ln(B - 1) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right\} \quad (4)$$

Where

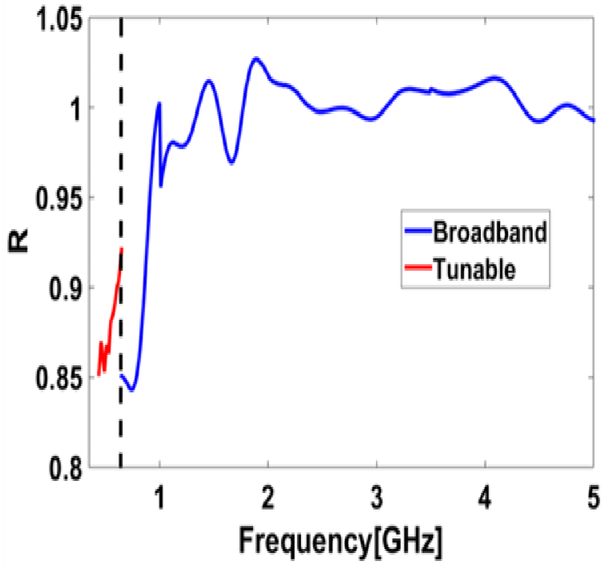
$$A = \frac{Z_0}{60}\left\{\frac{\varepsilon_r + 1}{2}\right\}^{1/2} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left\{0.23 + \frac{0.11}{\varepsilon_r}\right\}$$

$$B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_r}}$$

High Frequency Simulation Software (HFSS) was used for all simulations in order to verify the supplied antenna.



(a)



(b)

Figure 2. shows the mean effective gain ratio and the envelope correlation coefficient for the broadband and tunable operation regions, respectively. for the lower range of frequencies.

To achieve polarization variety, two reconfigurable UWB antennas are positioned orthogonally on an RT/Duroid 5880 substrate that is 31 mils thick. Figure 1(a) displays the dimensions of the two-antenna design. The reconfigurable UWB MIMO antenna's broadband and adjustable performance are displayed in Fig. 1(b). It is evident that in the tunable zone and in the broadband region, the return losses of both antennas are the same. On the other hand, employing different grounds and orienting both UWB antennas orthogonally to one another will result in strong isolation between the two antennas. The isolation between the two antennas is less than -25dB throughout the whole band, as shown in Fig. 1(c). Diversity in MIMO MEGs, or mean effective gain, are computed [3–4]. CC measures the degree of independence between the emission patterns of two antennas; generally speaking, an ECC of less than 0.5 is seen as rational. The approved MEG ratio of both antennas should be near to 1. MEG is another diversity metric. It is defined as the ratio of the mean received power to the mean incident power. The suggested reconfigurable UWB MIMO antenna elements have low correlation (ECC < 0.5), as shown in Fig. 2(a). The MEG ratio (R) of these antennas is nearly one, as shown in Fig. 3(b).

III. CONCLUSION

The design and diversity parameters of a reconfigurable UWB MIMO antenna system are presented. A tunable frequency extender increases the UWB antenna's operating frequency. corresponding network while maintaining a small size. The suggested antenna has the reconfigurability and diversity that are needed for next-generation wireless communication systems. Additionally, it may be applied to build a 2x2 MIMO system, which consists of 2 broadcast and 2 receive antennas.

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