E-ISSN: 2321–9637
Volume 1, Issue 5, December 2013
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

Design of 3D Fractal Tree Antenna for MIMO Channel Improvement

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Abstract:
This paper trying to analysis and improve the capacity of single MIMO channel link with the help of pattern diversity. With the help of 3D Fractal Tree Antenna (FRA). we are observing Gaussian noise and azimuthal angle in a MIMO system when we are analyzing the fractal antenna for several degrees of freedom, number offractal stages, angle between branches and parent to child branch scaling length. Simulations of fractal tree arrays are conducted so their spatial correlation and MIMO channel capacity can be observed. Capacity improvement from two different FTA is reported, assuming a perfect feedback channel.

Index Terms — Antennas, Diversity methods, MIMO systems,coupling, fractals,

I.INTRODUCATION

The fourth generation (4G) based mobile communication is rapidly improving for better improving broadband connection and better quality of wireless connectivity satisfying the high speed data rate such as application software and video streaming from a smart phone [1] with the MIMO system in which multiple antennas are used at both transmitter and receiver , have been proposed to achieve high data rate due to an improvement in spectrum efficiency . There are several polarized models taking into account both the azimuth and elevation angles. To derive higher data rate and find out the azimuth and elevation angles and for better quality we are proposing the fractal antenna with the help of 2D fractal antenna we are deriving the 3D fractal antenna for one of the most important topics is to improve the spectrum efficiency of the mobile communication system. For Long Term Evolution (LTE) and LTE–Advanced, Multiple Input and Multiple Output (MIMO) technology has been introduced to improve the system spectrum efficiency, where the physical signal processing has been extended to the spatial domain. Fundamentally, the joint spatial-temporalfrequency signal processing is expected to boost the peak data rate by 100 times and the spectrum efficiency by 2-3 times in comparison with what has been achieved in the 3rd generationit is possible to further enhance the spectrum efficiency if one can exploit an additional signal processing domain in addition to the so-called spatial-temporal-frequency domain. For the MIMO technology in LTE/LTE-Advanced, only the horizontal plane of the spatial domain has been utilized in the spatial signal processing. For the conventional MIMO technology, the system capacity could be significantly improved even without changing the number of antenna elements at the MS. Such properly configured 2 dimensional (2D) antenna arrays at the BS are termed as 3 dimensional MIMO (3D MIMO) or full dimension MIMO (F-MIMO). Recently, 3D MIMO or F-MIMO has been identified as one important technique for performance enhancement.

The performance of an array of reconfigurable fractal tree antennas to improve Multiple- Input Multiple-Output (MIMO) systems by controlling the degree of intentional mutual coupling between array elements. The dynamic control of coupling between array elements imbues the system with the ability to change the far field gain pattern of either element, enabling pattern diversity for enhanced MIMO capacity. The Reconfigurable Printed Fractal Tree Array (RPFTA) exploits the large number of degrees of freedom of a parameterized reconfigurable fractal tree for the purpose of improving MIMO channel capacity for a single communication link. The thin-wire 3D fractal tree antenna was extensively analyzed through simulation in [4], {6} which includes results on the wideband frequency agility of a reconfigurable 3D fractal tree antenna.

In the paper we are describing the paper into section 2 describe the design of 3D fractal antenna section 3 explain the MIMO techniques with 3D fractal antenna. Section 4 describes the simulation result and conclusion

II .ANTENNA DESIGN

A fractal is a rough or fragmented geometric shape that can be split into parts, each ofwhich is (at least approximately) a reduced-size copy of the whole." A fractal antenna's response differs markedly from traditional antenna designs, in that itis capable of operating with good-to-excellent performance at many different frequenciessimultaneously the fractal antenna an excellent design for wideband and multi-bandapplications

II.IPythagorean Tree

The Pythagorean tree is a plane fractal constructed from squares. It is named after Pythagoras because each triple of touching squares encloses a right triangle, in aconfiguration traditionally used to depict the Pythagorean Theorem. Increasing the number of segments may increase the coupling between branches. Size ofthe first segment determines the one of the resonant frequency of the antenna. Scalefactors may decide the ratio between the successive resonant frequencies. [1] Thebranching angle also affects the coupling. However it does not affect the ratio of resonantfrequency if the lengths and widths of the branches are not dependent on the angle.

A. 2D Fractal Antenna

A fractal patch antenna is first designed to resonate at 2.4 GHz. The relation between the dimension of an equilateral triangle patch and the resonant frequency is given in Equation

$$fm = \frac{2c}{\frac{3a(\epsilon)1}{2}}(m^2 + mn + n^2)^{\frac{1}{2}} \quad (1)$$

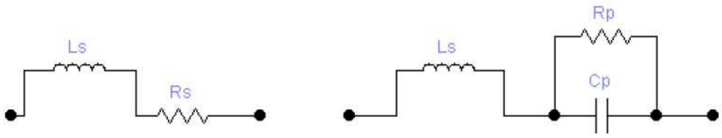

Fig 1 the equality circuit for the pin diode for the design of fractal antenna.

In the equation c is the velocity of emf in free space ϵ is the dielectric constant of the substrate m,n are the corresponding integers ‘a’ is the side length of the equality triangle.

II.II Design of 3D Fractal design with fractal tree array

By Fractal tree array(FTA) antenna in which all antenna elements are in one plane**.** we focus on 2D FTA in the x-z plane in 3D space. FTA is the most basic antenna structure of the MIMO systems. The antenna elements are arranged to form a 1 dimensional antenna array. In this paper**,** we assumed the antenna elements placed along the x-axis and 3D channel coefficients of FRA is analyzed in this subsection.

Antenna Elements

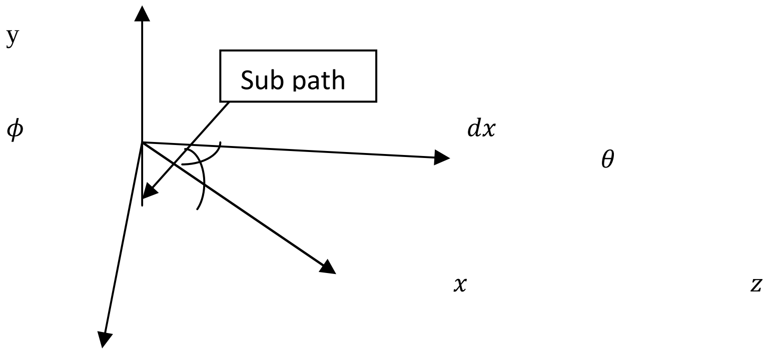

Fig 2 Design of 3 D fractal Antenna by Geometry Design

As shown in the figure 2, the symbol ϕ, θ the elevation angle and azimuth FRA antenna elements are equispaced with an interval of d^xon x axis We denote the channel coefficient for the nth multipath component (n

= 1,2,….N) as $H_n(t)$ which represents the transmission from the BS to MS. The proposed channel coefficient describes the propagation of mixed horizontal and vertical amplitude of each subpath. Then the (u,s)th component (s =1,…s; u= 1…,u) can be expressed as

$$ynm = |H|cos\epsilon v.\, cos\phi nm + |H|sin\epsilon.\, cos\phi nm.\, sin\phi nm(2)$$

By applying the 3D fractal antenna on a MIMO system we observe the relation of MIMO with the help of fractal antenna design for this derivation and to obtain the results, here we are first designing the 3D fractal antenna.

A. Description of a Fractal Antenna Array

The FTA is designed to be resonant near the center of the ISM band for wireless LAN at 2.44 GHz. Sinceeach antenna element is a center fed doublet, each side of the base of the tree must be fed 180 degrees out of phaseso that it will radiate efficiently. The design of a 2.4 GHz microstrip via-hole is obtained from [6] to feedeach antenna efficiently, as shown in Fig. 2. In addition, the lumped element (R-L-C) equivalent model for the S parameters of a commercial RF PIN diode switch in the open and closed bias states is obtained from [6].
Incorporating these two aspects enhances the fidelity of the EM simulation so that when the FTA is built, the simulated design will be an accurate predictor of performance.

B. *Antenna Performance*

As part of this work, the FTA shown in Fig. 4 is simulated in the MATLAB simulation tool [10] while thenetwork of RF PIN diode switches are modeled in various configuration states for the left and right elements. Fig. 3is the H-Plane 2D far field gain pattern for the previously described two stageFTA for five of its many possibleconfiguration states. It is interesting to note that if the gain pattern is mirrored around its vertical axis then the peaks of the lobes are often aligned with the nulls of the mirrored antenna, leading to angles of arrival with lower spatial correlation values between antennas and possibly enhanced MIMO capacity. Fig. 4 shows that this antenna has a minimum return loss of - 6 dB or lower at 2.44 GHz for the simulated configurations while the minimum of the return loss for all intermediate switch configuration states lie between the "All On" versus "All Off" states.

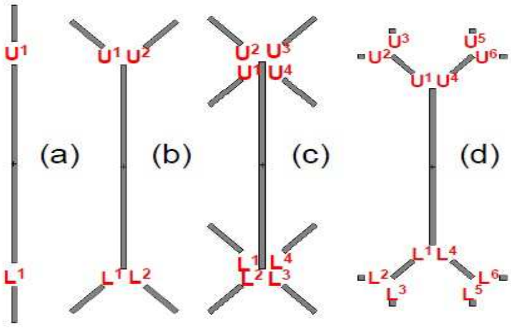

Fig 3 Design of 3D fractal antenna
(courtesy: Evaluation of the Reconfigurable Printed Fractal Tree Antennafor Enhanced Pattern Diversity in MIMO Systems)

The design process for FTA is to iteratively search for an acceptable return loss (-10 dB or as close aspossible) at the desired center operating frequency (2.44 GHz) when the antenna is switched into its longest andshortest configurations.

III. CAPACITY IN MIMOCHANNEL MODEL

A narrowband, non-frequency selective MIMO systemwith $N_T$transmit and $N_R$receive antennas has thefollowing expression for the received signal at thereceiver:

X = Hx + N (3)

Where X is the N_{x1} received signal vector , X is the N_xT_1 transmitted signal vector , H is the N_r* $N_t$channel transfer matrix and N denotes the additive white Gaussian noise. In a double side band spatially correlated Rayleight faded MIMO channel , the channel matrix H_x is found by the Kronecker model [8] as:

$$\underline{H = R_r^{\frac{1}{2}}.H.R_t^{\frac{1}{2}}}(4)$$

Where R_r,R_t N_r,N_t denote the receiver and transmitter spatial correlation matrices for the receiver and transmit array and

$H \epsilon C^{NXN}$ is a matrix of complex Gaussian fading coefficient.

The average spatial multiplexed MIMO capacity where equal transmit power is allocated to each antenna is

$$C = \frac{1}{N}\sum_{n=1}^{N} \log\left[\det\left(Y + \frac{snr}{Nt}.Hn.\frac{H^h}{N2}\right)\right] \quad (5)$$

where $N_{chz}$is number of discrete i.i.d. realizations of N_r * N_tGaussian distributed randomnarrowband channel mixing matrix, .The**H** matrices obtained for each channel mixing matrix arenormalized via the Frobenius normalization factor, $N_F$as defined by (4) where $\|.\|_f$ is the Frobenious norm.

$$Nf = \sqrt{\frac{||H||2}{Nt.Nr}} \quad (6)$$

The spatial correlation matrices for the transmit and receive arrays are found by (7). This modified version ofthe 3D antenna spatial correlation function uses an isotropic antenna as the common basis of comparison.

$$Rmn = (|\frac{\oint\{Yr\ .E\phi m(\varphi).E\phi(\varphi)P\phi(\varphi)+E\phi(\varphi)P\phi(\varphi)\}}{\{\oint Yr|E\phi(\varphi)|P\phi(\varphi)+E\phi(\varphi)P\phi(\varphi)\}})2 \quad (7)$$

Where φ represent the coordinate point (ϕ, θ) in the spherical coordinate system and the constants of solidangle integration in spherical coordinates in (8) are

$$\oint d\varphi = \int_0^{2\Pi}\int_0^{2\Pi} sin\phi d\phi \quad (8)$$

$Y(\phi), Y(\theta)$are the power angular spectrum (PAS) for the theta and phi polarization, which are defined by a Laplacian distribution with an angular spread of 30 degrees for an typical indoor propagation channel [12]. The XPR term is the cross polarization ratio ($P_{v/}P_h$) of the PAS, set to unity in this case, and E_m and En are the theta and phi polarized electric fields of the m^{th}antenna. In the case of isotropic ally normalized spatial correlation factor, the following unity equalities must be met:

$$\oint\{|E\phi n(\varphi)|2 + |E\phi m(\varphi)|2\}d\varphi = 1$$

$$\oint\{|E\theta n(\varphi)|2 + |E\theta m(\varphi)|2\}d\varphi = 1 \quad (9)$$

Additionally, the following unity equalities must be met so that the PAS has the required property of a discretePDF.

Since each FTA antenna configuration state has a different system efficiency due to its matching andradiation efficiency being a function of the FTA switch configuration, it is necessary to reintroduce the systemefficiency back into the “effective” spatial correlation matrix as follows [1]:

$$Rmn = Rmn\sqrt{\psi m(1-\kappa m).\psi m(1-\kappa n)2} \quad (10)$$

Where ψm andκnmisthe reflection coefficient and radiation efficient of the mth array element, respectively.

Figs. 5 and 6 show the capacity CDFs for two different FTA obtained by evaluating several possible transmitand receive MIMO array combinations for 500 instances of the channel mixing matrices, , **H** in a Monte Carlofashion. Then, by assuming that the perfect channel state information exists on the transmit side of the link, the Txand Rx MIMO array configuration that maximizes capacity is selected for each channel realization as the“Optimal” configuration. of the simulated array configurations.

IV. Result and Simulation

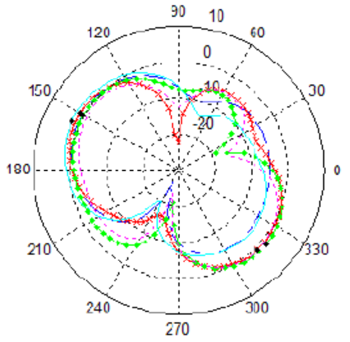

Fig 4 : gain pattern of antenna for 2stages fractal antenna

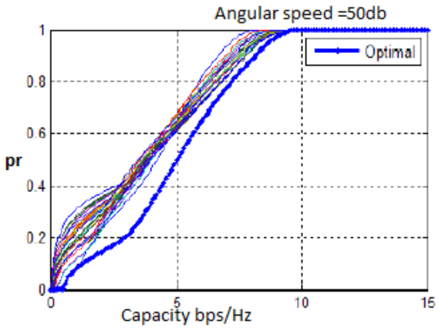

Fig 5 capacity of one stage, parent- child scaling 0.1lambda spacing

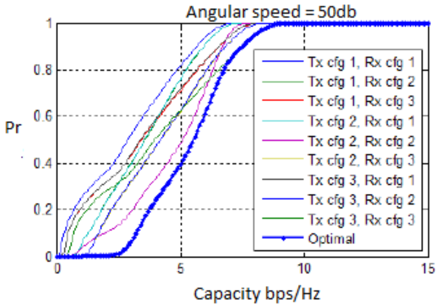

Fig 6 capacity of two stages, two branch for fractal antenna

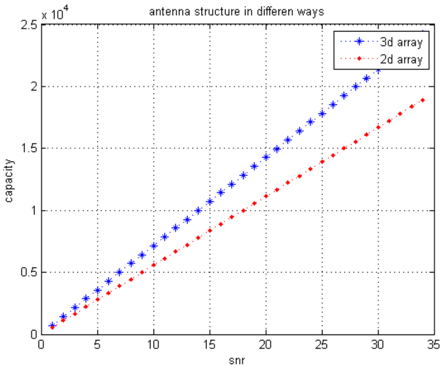

Fig 7 compression of two stage in 90o in different sets

V. CONCLUSION

The results show that theFTA effectively explains pattern diversity through its unique shape andproperties. Simulations of MIMO capacity with a perfect feedback channel show that the two stage, two branchFTA has a higher improvement over the one stage. This model may be considered unrealistic so performance in a multiple cluster model, raytracing model, or measurement will be considered in future work.

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E-ISSN: 2321–9637
Volume 1, Issue 5, December 2013
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