Intelligent Multiband Mobile Array Antenna for Software Defined Radio

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***Abstract*—This paper presents a novel concept for design of intelligent multiband mobile array antenna for Software Defined Radio [SDR] applications. This array is incorporated in the metastructure [MS] which is excited by the near field of the parent antenna in hypermode for multiband applications. The design of the MS depends upon these modes at different bands. The MS can be driven by a phase shifting network to enable control of beam by the intelligent baseband signal processing.**

***Index Terms* — Metastructure, Mobile Intelligent Antennas, Smart Antennas, Hypermodes.**

I. Introduction

The growing demand of multiplicity of protocols and frequencies in mobile communication systems, calls for antenna systems which can meet the rising diversity [1], [2]. Till date there has been substantial amount of work on antenna design for base station applications. Whereas, in case of mobile station applications there has been considerable compromise in antenna design. This constraint is mainly due to the diversity of frequency, diversity of protocols and structural limitations. This paper attempts to provide a concept which will offer partial solution to this emerging conflict.

The realization of the proposed concept consists of a primary exciter[PE] being a parent antenna[PA] with a metastructure[MS] excited in its nearfield[NF]. The theory is based on convergence of excising concepts of NF [3] excitation of MS and array design [4] concepts. In most studies the MS has been designed to suppress unwanted modes [5] and in addition, radiation at hypermodes is said to be undesirable. This paper attempts to treat the MS as a radiating element at higher order hypermodes, thus creating a directive antenna array that can be intelligently controlled using phase shifters. The hypermode frequencies are much higher than the dominant mode frequency of the PA and hence the application can be extended to much higher frequencies with considerable size reduction. This can also result in lesser unwanted radiation towards the user in case of cellular mobile applications.

The proposed theoretical concept is explained briefly in Section II. Section III includes discussion on various aspects to prove the proposed concept, followed by the supporting simulation results compiled in Section IV.

II. THEORETICAL CONCEPT

The proposed theory is based on the concept that, when an array of parasitic elements is placed in the NF of a radiating antenna, there exists a magnetic coupling between them due to proximity effect. Since the parasitic elements are not directly fed, they act as secondary radiators or MS. The far field radiation pattern of the PA can now be altered by nature of the MS which depends on the current distribution on PE at hypermode frequencies. Since the MS is an array, a high gain directional pattern can be achieved. A suitable MS configuration such as fractal geometry can ensure multi-frequency operation. Also, integration of phase shifting circuits within the MS shall form a microwave circuit-antenna module that enables controlled beamsteering. The phase shifters can be controlled by the baseband signal processing to provide desired shift in the beam and also frequency agility for a chosen channel. Also, an appropriate choice of the PE and MS with suitable choice of dielectric materials can result in size reduction and can be made conformal.

III. PROOF OF CONCEPT

A. *Antenna Configuration*

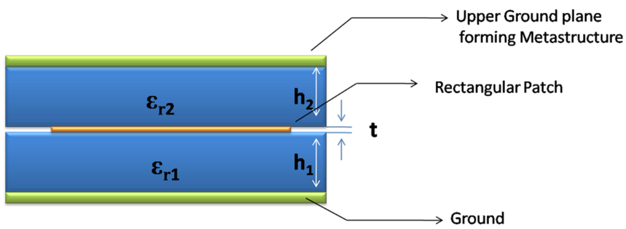


Fig. 1: Cross-section of the antenna structure.

An inset fed rectangular microstrip patch antenna[RMSA] [6] [7], matched for return loss at the dominant mode at 915MHz forms the primary exciter. This PA is sandwiched between two 2.33TLY-3 62mil substrates thus forming a triplate structure shown in Fig. 1. The upper ground plane on the RMSA forms the MS.

B. *Methodology and Metastructure Design*

To begin with, RMSA, the PA is designed using the empirical formulae [8] and simulated. The patch is extensively studied using cavity model for field configurations and current distributions at hypermode frequencies and their characteristics, for a frequency window of 0.9 GHz to 6 GHz. The RMSA radiates at both the dominant and hypermode frequencies [9] and their radiation patterns are carefully observed. Single lobe directional pattern is seen at dominant mode as compared to increased gain but growing number of lobes at higher order modes. The RMSA is then enclosed between the substrates and ground planes on either side thus forming a triplate structure with the upper ground plane being the MS. The MS is designed to resonate at specific frequencies of interest. This antenna configuration is simulated using the High Frequency Structural Simulator(HFSS) software [10]. In this paper MS comprises of circular slots designed at specific hypermode frequencies using empirical formulae (1) and (2) [8].

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon_r}} \quad (1)$$

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

IV. SIMULATIONS

The RMSA is a directive antenna with broadside pattern at the dominant mode. When the triplate structure without slots in MS is simulated, energy is trapped between the MS and the patch. Hence only surface wave radiation exists leading to the two lobe endfire radiation shown in Fig. 2. Simulated pattern

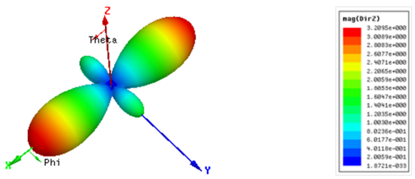


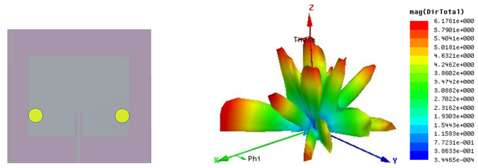
Fig. 2: 3D radiation pattern of the triplate antenna structure.

for MS with two circular slots for hypermode frequency 5.9545GHz, TM_{64} with a=8.9045mm is shown in Fig. 3a. Similar results for hypermode frequency 2.4048GHz, TM_{22} with a=22.9559mm are as in Fig. 3b. Multi-frequency operability of the triplate antenna configuration is demonstrated by including slots of varied diameter. Radiation patterns for MS comprising of slots at both 5.9545GHz and 2.4048GHz hypermode frequencies are shown in Fig. 3c and Fig. 3d wherein, an array affect can be observed.

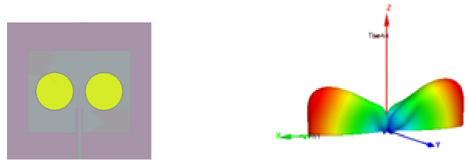
CONCLUSION

In this paper an attempt is made to present an approach to design a *Multiband Multibeam Directional Antenna* which can operate at different frequencies. It is demonstrated that, the MS enhances the radiation characteristics of the primary exciter and also provides multi-frequency operability. Further work will be done to provide phase shifting to the beam which can be controlled intelligently by base band processing.

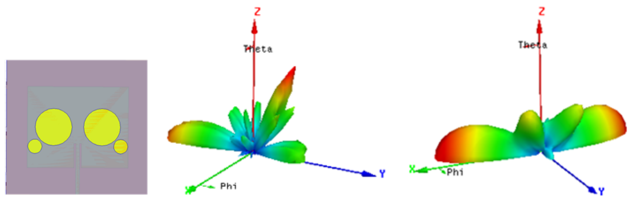
The proposed antenna design will prove to be extremely useful if realized in a miniaturized form using MEMS technology for wireless applications at MM and Sub-Terahertz frequencies.



(a) At 5.9545GHz, TM_{64} hypermode.



(b) At 2.4048GHz, TM_{22} hypermode.



(c) (d) At 5.9545GHz (e) At 2.4048GHz

Fig. 3: Layout of the MS with circular slot array of two hypermode frequencies and their respective 3D radiation patterns.

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