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Abstract- Beam scanning have found great demand in the field of wireless communication, satellite communication, radar, etc. [1,2]. These applications are generally covered by phased array antennas [3], where several elements are grouped together in a linear or planar special configuration. The radiated beam is determined by the vector addition of the electromagnetic fields radiated by the individual elements. Present proposal a novel technique of Tunable Multi Layer Multi Dielectric High Impedance Surface (TMMD-HIS) is embedded with array antenna, making it possible to obtain a beam scanning angle of 40 degree (from -20 degree to +20 degree) without the need of expensive active components. The major advantage of proposed concept is that the array have a negligible mutual coupling between radiating element this is happen because of suppression of surface wave. In built phase shifting is provided which reduces the structure size and proportionally cost. simulated results showing the effectiveness and compatibility of proposed concept.

Keywords: *reflection phase, width of patch, gap between patches, height of substrate, operating frequency, band width.*

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BEAMSTEERINGOFANARRAYANTENNAUSINGTUNABLEMULTILAYERMULTIDIELECTRIC-HIGHIMPEDANCESURFACEREFLECTOR

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Praveen Kumar Kancherla [α] & Dr. Habibulla Khan [σ]

Abstract- Beam scanning have found great demand in the field of wireless communication, satellite communication, radar, etc. [1,2]. These applications are generally covered by phased array antennas [3], where several elements are grouped together in a linear or planar special configuration. The radiated beam is determined by the vector addition of the electromagnetic fields radiated by the individual elements. Present proposal a novel technique of Tunable Multi Layer Multi Dielectric High Impedance Surface (TMMD-HIS) is embedded with array antenna, making it possible to obtain a beam scanning angle of 40 degree (from -20 degree to +20 degree) without the need of expensive active components. The major advantage of proposed concept is that the array have a negligible mutual coupling between radiating element this is happen because of suppression of surface wave. In built phase shifting is provided which reduces the structure size and proportionally cost . simulated results showing the effectiveness and compatibility of proposed concept.
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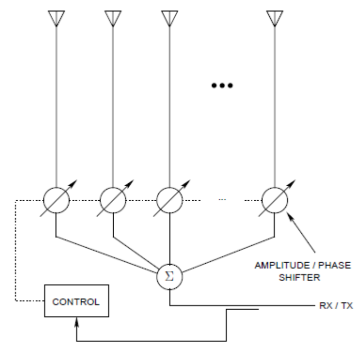
I. Introduction

In RADAR systems beam scanning is necessary to track mobile targets, or to scan the physical area of a targets. In point to point communication links where one or both of a terminals are mobile (especially in satellite communication systems) the beams of both antennas must track with the movement of the terminals so that adequate communication quality is maintained. To have a such adaptability, the antennas are mechanically steered. but this mechanical steering has limitations in terms of tracking speed and flexibility.

Antenna arrays, as the name suggests, consist of a number of antenna elements assembled together to form a larger antenna system. There are two subclasses of antenna arrays.

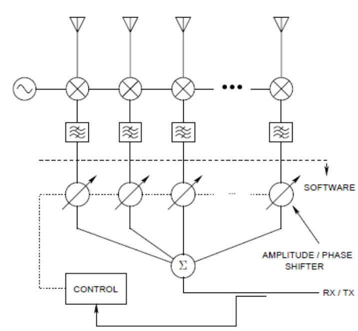
a) Depending on Feed Method

First each element in a array is actively driven by independent radio frequency (RF) sources, and corporate feed method. whereas arrays based on actively driven elements tend to be built such that the elements are separated by a significant distance (typically a half-wavelength or more) to avoid mutual coupling between radiating elements.



(a) RF beam-former

A general diagram of an antenna array utilizing actively driven elements is shown in Figure 1.1(a). It consists of a number of radiators, each driven by a signal whose amplitude and phase are controlled independently [4]. Through manipulating the amplitude weighting and phase shift applied to each of the elements, beams can be formed and steered by the array.



(b) IF beam-former

The diagram in Figure 1.1(b) shows an alternative realization whereby signals from the array are collected at an intermediate frequency (IF). This is done so that phase shifting and amplitude weighting can be done at lower frequencies, which can reduce costs. More frequently, however, this is done so that operations that were traditionally implemented at radio frequencies (namely phase shifting and amplitude weighting) can be performed digitally in software

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through transforming the analog IF signals to digital signals using analog-to-digital converters. The point at which analog-to-digital conversion takes place is denoted by the dashed line in Figure 1.1(b).

Antenna arrays, despite their great potential as reconfigurable antenna platforms, explained above in both the approaches possess a number of major shortcomings that makes the deployment of reconfigurable antennas based on the classic array implementation impractical and inexpensive.

These include the following:

Cost of RF hardware Antenna arrays, regardless of whether they are implemented as shown in Figure 1.1(a) or (b), require a substantial amount of RF hardware. The implementation shown in Figure 1.1(a) requires a separate RF phase shifter for each antenna element, plus an amplitude controller if amplitude weighting is to be used as well. These components tend to be costly and bulky, increasing the size of the array platform and making it more expensive. The implementation of Figure 1.1(b), while eliminating the need for the RF phase shifters and amplitude controllers, nevertheless requires a substantial amount of RF hardware in the form of frequency conversion equipment, filters, and so on. The complexity of these systems increases when they are used in both transmit and receive modes, where additional components such as amplifier chains, RF switches, and other components are required. These components are generally assembled into a unit called a transmit-receive module (TRM). In antenna arrays, TRMs must be duplicated for each of the antenna elements in the system. At high frequencies, these components still tend to be very expensive, especially components designed for use at millimetre-wave frequencies where this project is ultimately targeted. This makes antenna arrays generally a costly proposition. Indeed the cost of the RF hardware in antenna arrays has prevented them from being widely deployed, even at lower RF frequencies.

Feeding difficulties associated with large arrays The scanning angle of antenna main lobe is determined by the feed network. Array antennas require that each element is actively fed by an RF signal. For small arrays, this is usually not a problem, but for large arrays, feeding the array can become a logistical nightmare. However, a serious problematic issue is feed loss in the network itself, which is a particular problem at high frequencies. The large number of feed networks required for large high-gain arrays compounds the loss problem, producing an upper limit on the realizable gain from the array. Additionally, the feed network is often a source of cross-polarization in planar antenna arrays.

Another is to use beam forming networks for multi beam array. Multi beam formers are either the networks [5, 6] (butler matrix, Blass matrix) or quasioptical system lens (Rotman lens).

The input impedance of each radiating element changes from its initial value due to mutual coupling, this variation is unstable when we change the direction of radiated beam. this phenomena causes the mismatching between the output impedance of a beam forming network and input impedance of elements at different given beam directions if BFN is properly designed.

The angle blindness [7] i.e the array can radiate no power in certain angles. 4 and 5 are mainly occurring because of mutual coupling.

b) Proposal of Research work

Antenna arrays are therefore a natural choice as the foundation for any reconfigurable antenna platform. Unfortunately, the design of a large antenna array is complicated by issues of cost, complexity, and loss, as discussed in the previous section. Indeed, shortcomings of traditional array architectures given motivation of this research project. The TMMD-HIS reflector have none of the cost, complexity, and loss of antenna arrays. hence embedding both concepts mutually exclusive way could provide attractive reconfigurability in antenna, with improved performance and reduced cost. several papers on beam steering of antennas based on 2D EBG structures were presented [8,9]. In some papers authors demonstrated 2D EBG structures in reducing the mutual coupling[10][11]. where the suppression of EM wave is done only in two directions. Present paper a novel proposal of TMMD-HIS is a three dimensional Energy Band Gap Structures (EBG). It is going to suppress the EM waves in all three dimensions. This structure has a provision of tuning its surface impedance by varying reactive capacitance in its structure. As the surface impedance is varied interne varies the reflection phase. This inbuilt phase shift operation is utilized to steer the beam of an array antenna.

II. Unit Cel Meodeling

The structure of Multi Layer Multi Dielectric High Impedance Surface consists of an optically planar ground plane, dielectric substrates arranged in ascending order, square metal patches (protrusions) arranged in three dimensionally and metal vias joining the metal protrusions to ground. the arrangement is shown in figure 1.

The unit cell has following dimensions; thickness of lower substrate t =62mil with a relative permittivity of ε_r =2.2 and loss tangent 0.0009, diameter of via d =0.65mm, width of patch w = 41mm, gap g = 2.5mm, hidden layer patch width Hw = 46mm height of TMMD-HIS h = 3mm and an air is considered as another dielectric exist between top and bottom layers. This structure resonates at 1.89GHz.

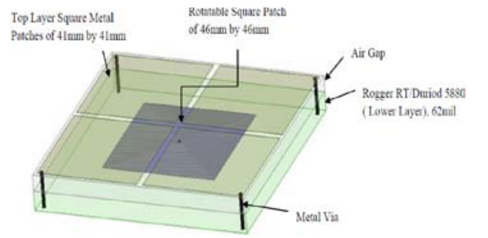

Figure 1 : Description of structural parts unit cell

III. Dispersion Diagram

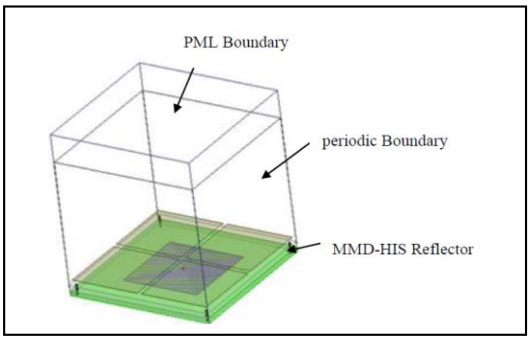

Figure 2 : Unit cell Measurement setup

The Dispersion diagram shown in figure 2 consists of TM wave band bellow the lower line or mode1, this follows the light line up to certain frequency then it becomes very flat suddenly. TE wave band above higher line or mode2 is begins at high frequency and continues upward with a slope and travelled with light line of a speed less than the velocity of light in vacuum. The band gap that spans from the edge of TM band to the point where TE band crosses the light line is called surface wave band gap. During this band gap both TE and TM waves are suppressed.

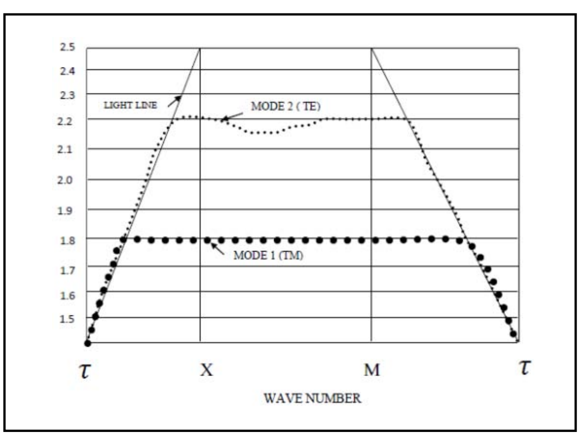

Figure 3 : Dispersion Diagram

IV. Reflection Phase Measurement

A proposed unit cell is designed and executed in Ansoft HFSS software. By placing in a box to which a periodic boundaries are applied and extended to infinity. Finite Element Method is adopted to analyze the proposed unit cell.

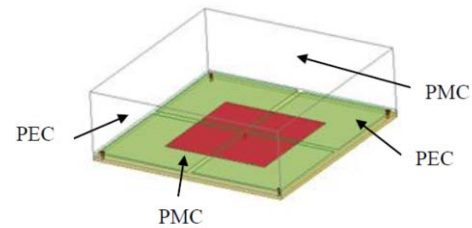

Figure 4 : Reflection Phase

The diagrams in figure 4 is showing perfect electric boundary at opposite walls of unit cell box, and perfect magnetic boundary at opposite walls of remaining unit cell box. The figure 3 is showing the reflection phase of normally incident plane wave on TMMD-HIS structure versus frequency. At low frequencies this structure reflects with a +180^0 phase shift as the frequency increases the phase slops downward and crosses through zero degree point and reaches to -180^0 the frequency at this phase is high. The point of intersection of the phase curve with zero degree line, frequency at this point is considered as operating frequency. The region betwee+87.92 degree to–176.08 degree shown in Figure3 with highlighted region reflects the plane waves in phase with transmitted wave. This region functions like Perfect Magnetic Conductor (PMC). This range corresponds to surface wave band gap. The region before and after to highlighted region functions like ordinary reflector.

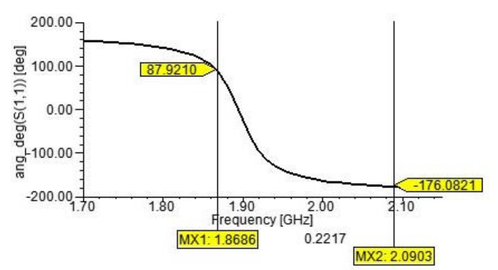

Figure 5 : Reflection Phase

V. Transmission Co-efficient Measurement

Transmission co-efficient indicates how MMD-HIS forbids the propagation of EM waves To demonstrate this two micro strip patch antennas of individually feed with co-axial feed are considered both are operating within the electromagnetic stop band range as described in dispersion diagram. One column of multi Layer Multi Dielectric High Impedance Surface is incorporated between them. during the stop band region A minimum transmission coefficient level of -

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60dB is observed indicates MMD-HIS block the transmission of power between antennas. when we carefully observe the minimum transmission co-efficient level range is equal to band gap range obtained in dispersion diagram.

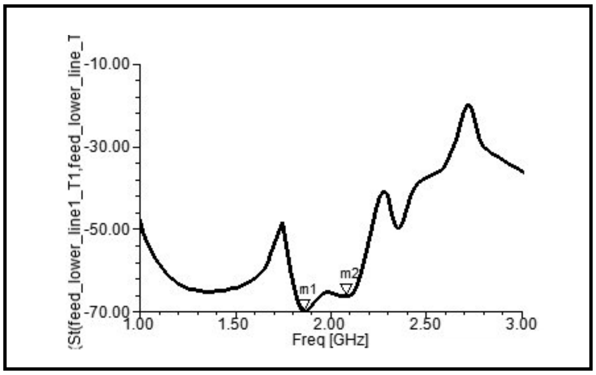

Figure 6 : S21 Characteristics

VI. Array Antenna Over Tmmd-his

MMD-HIS Reflector could be used to improve the efficiency of antennas [12], due to the suppression of surface waves, which are the predominant loss mechanisms in classical designs. Furthermore, the MMD-HIS Reflector can function as an artificial magnetic conductor (AMC) at a certain EM wavelength [13]. A metal surface, as an approximation of a perfect electric conductor (PEC), has a voltage wave reflection coefficient of -1, which causes a reflection and a phase shift of 180 degrees to the incident EM wave. Due to destructive interference, the PEC is undesirable as a ground plane for microstrip antennas. To overcome from this problem offset by a spacing of λ / 4 between the antenna and the ground plane [9], the problem of surface waves still persist for PEC ground planes. With an artificial magnetic conductor, as an approximation to a perfect magnetic conductor (PMC), there is an in-phase reflection. Having a PMC with a voltage wave reflection coefficient of +1 underneath a microstrip antenna increases the antenna's efficiency.

Another advantage of MMD-HIS Reflector is the integration of components. Usually the required high dielectric constant of the substrate needed for a high level of integration would be detrimental for microstrip antennas. However, by using an MMD-HIS Reflector, the antenna could be shielded from the substrate, enabling it to be integrated with other components on the same substrate [14]. similarly, MMD-HIS Reflector can be utilised to reduce crosstalk between neighboring components on a chip [10].

VII. Tuning of mmd-his & Beam Steering Measurement

The structure consists of a group of unit cells arranged in two by two array as a ground plane to 2by2 array of radiating patches. shown in figure.

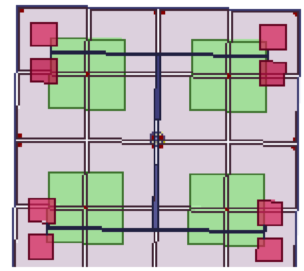

Figure 7 : Array of TMMD-HIS Unit cells

The tunable impedance surface that I used to demonstrate beam steering consists of pair of metal patches in attach with substrate arranged in layers, from the bottom we will give naming convention as layer 1 contains a substrate of Rogger/RT Duriod 5880 with a permittivity 2.2 and loss tangent 0.0009 consists of an array of four square metal patches (these are made to rotate around it's center position as reference with respect to layer 2 lower patches. in both clock wise and in anti-clock wise. For convenience from now we call them as revolving patches) on its top face, connected to conducting surface lying in other(bottom) face, by means of via which has a height of 62mil. layer 2 consists of Higher substrate of Rogger Ultima 1225 with a permittivity 2.5 and loss tangent 0.0015, contains an array of metal patches (protrusions) on its bottom face which are always fixed in nature) connected to bottom conducting surface of layer 1by means of via positioned at its corner, with a height of 3mm. such that this vias should not be obstacle to revolving patches. here on thing should take care that all the patches in layer 1 and 2 are connected to a common bottom conducting surface of layer 1 to maintain a resonant nature in the structure. Top face of layer 2 is embedded with 2by2 array antenna of square patches of miniature structure of 15.5mm*15.5mm, connected to RF power supply by following transmission line rules so that maximum power can be transferred to patches from RF source. here co-axial feed method is adopted and fed at location (-9.3252mm, 0mm, 2mm). An air gap of 1.4252mm is maintained between layer 1 and layer 2 which functions like air dielectric and develops a parallel plate capacitance. the complete structure is called Tunable Multi Layer Multi Dielectric High Impedance surface.

"The motion that is parallel to applied electric field contributes to change in resonance frequency". keeping this point in mind The beam steering operation is demonstrated here in three stages. Now the revolving square metal patches are made to rotate either in clock wise or anti clock wise direction by making it's center position as reference from it's zero position to ±45 degree with respect to layer 2 lower patches. The TMMD-HIS reflector embedded with a 2by2 array of square patch antennas shown. Left set of revolving patches are as taken as one unit and right set of

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revolving patches are taken as another unit for all stages of execution.

Stage 1: All the patches of layer 1are kept in reference position of zero degree. the radiation pattern obtained at this stage is taken as reference. as shown in above figure the beam is pointing to zero degree in phi direction.

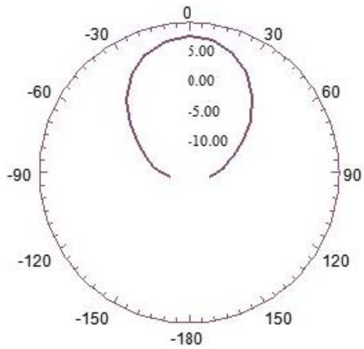

Figure 8 : Reference steer angle

Stage 2: Left set is allowed to revolve right set is kept constant in reference position (zero degree). As the set of plates starts revolving the over lapping area exist between patches of layer 2 and 1varied results change in capacitance reactance exist between parallel plates. since the resonating frequency of individual cavities formed by layer of metal plates and via structures depends on capacitance, so change in over lapping area leads to change in reflection phase results in beam steering to opposite direction. This is demonstrated by orienting left side set anti clock wise direction from zero degree to -45 degree (minus sign here indicates anti clock direction of orientation) with a step size of -15 degree by maintaining right side set is at reference position, the beam is steered to maximum right angle of +20 degree from zero degree when orientation is reaches to -45 degree.

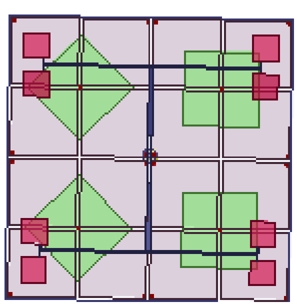

Figure 9 : Left Steer Measurement setup

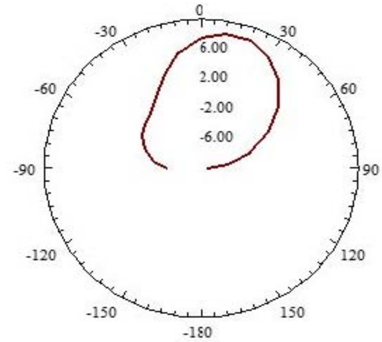

Figure 10 : Beam of patterns steered to +20 degree

Stage 3: Here right set is allowed to revolve left set is kept constant in reference position (zero degree). As the set of plates starts revolving, the over lapping area exist between patches of layer 2 and 1varied results change in capacitance reactance exist between parallel plates. since the resonating frequency of individual cavities formed by layer of metal plates and via structures depends on capacitance, so change in over lapping area leads to change in reflection phase results in beam steering to opposite direction. This is demonstrated by orienting right side set anti clock wise direction from zero degree to -45 degree with a step size of -15 degree by maintaining left side set is at reference position, the beam is steered to maximum right angle of -20 degree from zero degree when orientation is reaches to -45 degree. if the orientation is further increased beyond the -45 degree in both the cases we get repetitive characteristics.

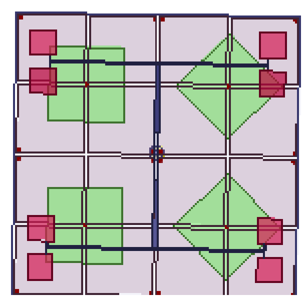

Figure 11 : Right Steer Measurement setup

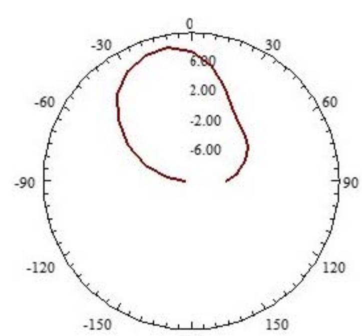

Figure 12 : Beam of patterns steer to -20 degree

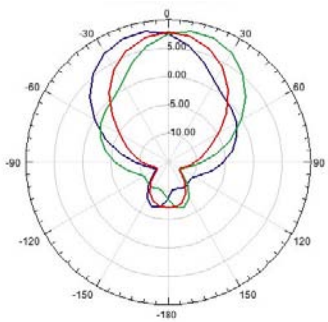

Figure 13 : Steering angles at -20, 0, +20 degrees

VIII. Conclusion

A novel TMMD-HIS embedded array antenna with a reconfigurable beam has been proposed, designed and simulated in Ansoft HFSS software. The simulated results obtained are presented are proving good agreement when compared with designs presented in literature so far.

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