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A SURVEY OF SEVERAL DECOUPLING MECHANISM FOR ELECTROMAGNETIC INTERFERENCE IN ANTENNA ARRAY ENGROSSED ON MTS AND MTM

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ABSTRACT

In high frequency Tele-communication and radar systems, synthetic A-Radar and Multiple Input-Output antenna systems are used. These antennas connected radiate in different pattern and in different polarization. Since the antennas are connected in arrays, it provides good gain and beam forming capability; such characteristics are preferred in latest communication technology. The size of antenna array should be in miniaturized size for the growing communication technologies requirement. This compact size antenna array creates crosstalk effects between the elements which are radiating actively and also induces inductive mutual coupling between the elements in the array. In order of increasing the Electromagnetic Interference immunity, various decoupling techniques were discussed. This paper provides an approach of using Meta Surface and Meta Material for preventing the mutual coupling between arrays. The various techniques used to suppress mutual coupling are Antenna with dielectric resonator, Resonators with complementary split ring, parasitic element, and Neutralization line. In this paper it is focused on Meta Material & Meta surface elements are utilized to reduce mutual coupling between the adjacent radiating elements. This method provides compact size antenna with high bandwidth and remarkable gain with good EM immunity.

Key Words: EM Interference, Antenna Array, Several Decoupling Mechanism, Meta-State and Meta-Material

1. INTRODUCTION

In order to improve the radio link capacity, Synthetic A-Radar and Multiple I/O Systems are used in telecommunication systems where the numerous numbers of Transmitting and receiving antennas are effectively utilized. In [2], [3],Multiple I/O system and Synthetic A-Radar system are widely used in mobile devices, these antenna are with low cost and low weight with etched pattern are its peculiar features. On using the compact size, array antenna increases the mutual coupling between elements which degrades the SNR factor, frequency offset estimation and arrival angle [4]-[6].The crucial factor is to reduce the interference between the etched pattern antennas which are kept close together[7], [8]. The use of decoupling networks in antenna arrays improves the isolation effect and thereby the interference will be reduced considerably [9]. Defective Ground Surface, Resonators with complementary split ring [10], meta-surfaces (MTS) and meta-materials (MTM) [11], [12] are some of the techniques for decoupling. The mentioned methods reduce or resist the current flow on the surface which is the main reason for improving isolation. For application in Multiple I/O systems and Synthetic A-Radar systems different methodologies are compared for suppressing the interference in the form of mutual coupling. The performance of antenna is characterized in terms of electrical isolation between radiating elements, operating frequency range, gain and efficiency. This survey paper gives in-light features about the ways of reduction of electromagnetic interference (Mutual Coupling) for improving performance of antenna arrays arranged in cluster

2. EM INTERFERENCE DUE TO MUTUAL COUPLING

When an antenna is working, the radiation from one antenna is attracted to a nearby antenna in antenna array systems, this creates an electromagnetic interference refers to mutual coupling. This type of interference alters the value of input impedances, radiation pattern and reflection coefficient.

Mutual coupling Interference

$M_{ij} = \exp(-2.d_{ij}(\alpha + j\pi)/\lambda)$----(1) ,

d_{ij} is the distance between i^{th} and j^{th} current element. Number of antenna elements n=1,2,..i,..j,….N, λ-wavelength of signal , α-level of coupling

3. SEVERAL DECOUPLING TECHNIQUES

A. DECOUPLING NETWORK

Isolation attained with the help of decoupling networks in Multiple I/O system and Synthetic A-Radar system. Discrete elements transformed the cross-admittance term to purely imaginary term. This discrete element is placed between Multiple I/O system and Synthetic A-Radar system to increase gain and to reduce the mutual coupling. The shunt element based decoupling network; indistinct line is used to increase the performances of the systems with considerable decoupling. The mutual coupling is further reduced by introducing an additional coupling route; this technique improves the far field properties. On using Diamond shaped ground resonator decoupling network, good amount of isolation say -27.6 dB is achieved which creates a good immunity for EM interference. Further, EM interference immunity can be achieved by using reactive dummy loads decoupling network. It provides a better isolation than DSGR decoupling network of -32 dB isolation.

B. PARASITIC ELEMENT DECOUPLING APPROACH

This method provides an isolation by extra coupling route [14], [15] by using parasitic element or carved slit like meandered slot, folded strip as decoupling approach. The level of improvement in isolation can be achieved by making opposing signal to travels in the extra coupling route. This technique has the advantage of small size, easy implementation. The parasitic element decoupling approaches are ground slit with open ended [17], square slit ring [16] and meandered feeding lines [18]. The performance of decoupling approach uses the open-ended ground slot and stepped slot feed line provides the lowest coupling or highest isolation of -22dB with 4dBi gain. When the square slit ring and stepped slot approach is used as decoupling approach it provides highest gain 8dBi with-20 dB isolation and for meandered feeding line maximum gain is 5.8dBi with lowest isolation of -15 dB.

C. DECOUPLING BASED ON DEFECTED GROUND STRUCTURE (DGS)

This Defected Ground Structure is defect like slits on the ground plane [19]. The defects like slit create back propagation along with appreciable isolation. It acts as band pass filter and controls the interference by reducing the surface flowing current. The reduction in surface current improves the decoupling performance. In this survey, few DGS like S-shaped periodic DGS, Square ring DGS and open-ended DGS performance are compared. On reviewing the S shaped periodic, it provides the highest isolation and efficiency of -55dB and 95%. For Square ring, the isolation obtained is about-25 dB with 81% efficiency, the miniaturized size is the advantage of this approach and open-ended defected ground provides an isolation of -20dB, this approach is a complex structure which is difficult to implement.

D. NEUTRALIZATION LINE DECOUPLING APPROACH

Neutralization lines [20] are used to reduce interference by using a metallic slot or lumped elements for transmitting electromagnetic waves. It is a metallic structure reduces the coupling between radiating elements. This approach neutralized any interference by creating a signal of equal amplitude with opposite phase on second route. The neutralization approach is widely used in Multiple I/O systems and Synthetic A-radar systems. Crossed neutralization lines with integrated inductors decoupling approach gives medium efficiency of 60% and good isolation of -23dB at low frequency range. A simple configuration with large dimension and high bandwidth neutralization line is stepped neutralization line provides -21dB isolation.

E. META SURFACE AND METAMATERIAL BASED DECOUPLING APPROACH

The advantage of Waveguide slot array (WSA) antennas is medium cost, good power handling capacity and very few losses, but this antenna suffers from EM interferences which reduces the gain, bandwidth and changes the radiation pattern. With good amount of isolation introduces in WSA antenna, this can be applied in future Synthetic A-Radar system and Multiple I/O systems. Decoupling can be built in WSA antenna systems by introducing Meta-Surface (MTS) and Meta-Materials between the slits for reducing the mutual coupling. Few techniques using MTS and MTM are:

1) Decoupling using Meta Surface Bulk Head- When Meta surface bulk head is placed between slits for reducing coupling, the isolation increased by 1.5 times more than when MTS bulk head is not placed between slits. This approach improves the gain, bandwidth and reduces phase errors.
2) Decoupling using Meta Surface isolator- Isolator is constructed with a square slot realized on rectangular micro-strip. The surface current distribution is controlled by the square slits, it avoid coupling and this provides high isolation at microwave frequencies
3) Decoupling using Isolator with oval slits- The isolator is obtained by placing linear slits between oval slits. Radiating oval slits are placed in horizontal and vertical directions. As before, the slits soak up the surface current and acts as isolator. Using slit decoupling lowest gain increases by 50% and highest gain increased by 25%
4) Decoupling using Meta Material Electro Magnetic Band Gap- This decoupling approach uses Meta Material Electro-Magnetic bang Gap is placed between the patches to avoid mutual coupling[21].The distributed E field is not allowed to couple to the neighboring elements which suppress the surface current flow. This structure of decoupling increases the isolation greater than 30 dB without any compromise in the radiation pattern.

5) Meta material substrate integrated waveguide slotted antenna arrays employing Metal-Fence Decoupling An approach for decoupling using Meta material substrate integrated waveguide (SIW) slotted antenna array[22].This structure provides an average interference of -10 dB on X-band to Ku-band frequency. The interferences were suppressed by placing metal fence between the radiation slits, which decreases the mutual coupling or EM interferences by 13dB and improves the gain by 10%.This approach also improves bandwidth without changes in radiation pattern. So this is suitable for Synthetic A-Radar and Multiple I/O systems.
6) U shaped Micro-strip Decoupling wall for SAR applications over X and Ku- bands In recent Multi I/O system and Synthetic A-Radar need more than 1 GHz frequency band for its operation. Waveguide slot antennas are used in this approach because of their high-power handling ability and good efficiency. In order to increase the frequency band, ridge type waveguide slot antennas are used. The isolation can be achieved by decoupling wall of U-shaped micro strip lines placed between the radiating elements. With the improved isolation, this approach provided the frequency band greater than 2GHz within the X-band and Ku-band.
7) Decoupling approach using Meta-material hexagonal slot resonator [23]. This approach is based on placing a Meta-Material decoupling structure with smaller patch between the radiating antennas. The meta-material is hexagonal slot resonator as decoupling structure. This technique provides a highest level of isolation, as well as high bandwidth and improvement of 100% in impedance match. This method is used in beam scanning systems.

Table 1: Comparison of various EM interference decoupling technique

Sl. No	Decoupling Techniques	Levels of isolation	Advantages	Disadvantages
1.	Diamond shaped ground resonator decoupling network	-27.6 dB	High Efficiency	Complex to implement
2.	Square slit ring and stepped slot decoupling approach	-20 dB	High Gain	Very Low Envelope correlation coefficient between arrays
3.	Parasitic Element square slit ring and stepped slot Decoupling Approach	-20 dB	High Gain	Design Frequency changed after using this decoupling
4.	S-shaped periodic DGS	-55dB	High efficiency	Huge Size
5.	Square ring DGS	-25dB	Compact size, Easy to implement	Low gain not suitable for communication
6.	Crossed neutralization lines with integrated inductors decoupling approach	-23dB	Provides good impedance matching	Reduction in bandwidth, Complex to implement
7.	Decoupling using MTS and MTM approach	-36dB to -83 dB	Low cost, Ease of manufacture process, Wide frequency band, Good Isolation	Leakage loss

4. CONCLUSION

Since many decoupling mechanisms are investigated to overcome the mutual coupling of radiating elements spaced close together. For many applications antenna arrays are used to obtain desirable radiation characteristics. But mutual coupling interference degrades the performance of antenna array. This survey gives an insight of various decoupling mechanism and electrical isolation between radiating elements can be improved by Meta-surface and Meta- material techniques. Though the other methods like Defected Ground Structure, Neutralization Line, Parasitic Element decoupling approach and Decoupling Network were also discussed and compared. In Multi I/O System (MIMO) and synthetic aperture radar (SAR) systems, high isolation is very important; the coupling effect degrades resolution capability and direction of arrival estimation. Reducing mutual coupling interference is an important area of research which has direct impact on the development of the next generation wireless communication-systems.

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