Asian Journal of Applied Science and Technology (AJAST)
(Open Access Quarterly International Journal) Volume 2, Issue 2, Pages 747-752, April-June 2018

A Decoupling Technique for Isolation Between Two Strongly Coupled Antennas Using Tunable Metamaterial Screen

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Article Received: 01 March 2018 *Article Accepted: 09 April 2018* *Article Published: 28 April 2018*

ABSTRACT

A decoupling technique is able to reach high-level isolation ratio because it isolates two antennas in near-field region. The isolation screen sandwiched between closely placed two monopole antennas proposed. The designed structure with dimension of 220 mm by 170 mm simulated. The transmission coefficient between the monopoles without metamaterial structure is about -22.75 dB. The decoupling is improved to -56dB when the conductive sheet is introduced between the monopole antenna. The effective decoupling of 33.25 dB is achieved with the aid of conductive sheet. When the metamaterial Omega structure is inserted between the monopole antenna, high isolation of -138 dB is achieved. Consequently, it provides high degree of isolation of 115.25 dB which reduce the mutual coupling between the radiators. This isolation is valid from 1.0 GHz to 3 GHz.

Key Words: Near-Mutual coupling in antenna, metamaterial screen, transmission coefficient.

1. INTRODUCTION

It is well known that mutual coupling between elements has long been a serious problem for multiple-antenna Systems [1]. Reduced the mutual coupling between closely placed antennas in near field region is not easy but important for many applications. A small number of technologies are invented to resolve this trouble. Following natural idea, the artificial magnetic conductors of the split ring type SRRs can play a significant role to suppressed the mutual coupling and improve the performance of antenna arrays [2]. A decoupling technique using the circuit approach for getting better the isolation between two closely placed antennas of the same frequency using two transmissions Lines and a shunt reactive component [3]. A double-layer mushroom structure is used to improve the inter-element isolation of a four-element antenna system is configured for multiple-input multiple-output (MIMO) applications[4].Recently, using multiple tunable metamaterial structures to improve high-level isolation in narrow band[5], [6]. Basic theory is introduced in Section II. In Section III, the design of the screen as well as the unit cell and model of simulated decoupling system are described.

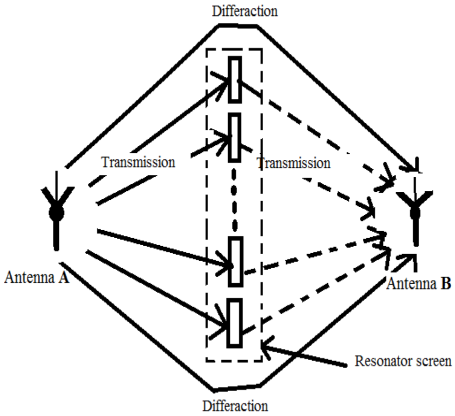


Fig: 1. Basic signal model of near field region

This model consist antenna A and antenna B (monopole antennas) with tunable metamaterial screen in the middle. Theoretical signal model for near-field transmission between two strongly coupled antenna elements with resonators in the middle, shown in fig.1. Antenna A transmits the signal to reaches the resonator rows and re-emits to antenna B, here tunable metamaterial screen act as a isolator. It decreases the mutual coupling between the two antennas. When the signals received by antenna B are totally cancelled, high-level isolation can be realized.

2. DESIGN OF THE SCREEN

The simulated structure with the measurement of 220 mm by 170 mm is simulated. This resonator screen is designed with four same columns.

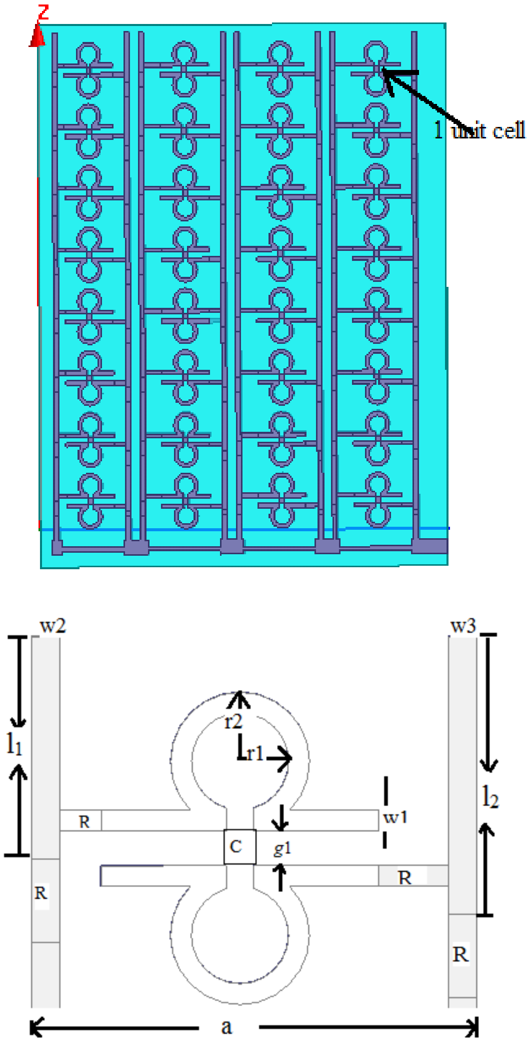


Fig: 2. Designed structure of screen and single unit cell

The dimensions are as follows: r1 = 8.5,r2=10.5mm, a = 30 mm, l1 = 8 mm, l2 = 10 mm, W1 =1mm, W2 = W3 = 1.5 mm, and g1 = 1.5 mm. where R,C denote the resister and capacitance. Each column has eight same unit cells, the eight unit cells are spilt into eight omega structure ,also used upside down (℧) to represent mho (in physics) structures. Bias voltages are feed at the bottom of each column through a connector. Thus the eight resonators within one column have the same bias voltage. But the voltages of different columns are individual. The other parts of this prototype are made of FR4 board.

3. DESIGN OF MODEL

3.1. Modelling of proposed structure

The stimulated structure is shown in Fig.3. Two straight up positioned same monopoles are designed uniformly with respect to a resonator screen. A monopole is a ground plane dependent antenna that must be feed single-ended. The monopole antenna should have a ground plane to be efficient, and the ground plane must spread out at least a 1/4 wavelength, or more, approximately the feed-point of the antenna. The size of the ground plane influences the gain, resonance frequency and impedance of the antenna. The height and radius of the monopoles is respectively 30.6 mm, 9mm and they resonate at 2.4 GHz. Their distance is equal being at the center of the tunable screen. The distance between these monopoles is 10 cm at 2.4 GHz. A circular ground plate with a radius of 20 mm is added for getting a more stable matching.

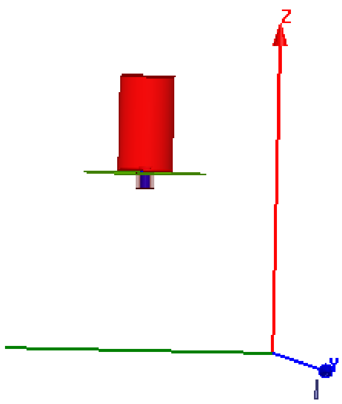


Fig: 3. Monopole antenna without screen

The stimulated metamaterial screen structure is using a single sheet FR4 board. An additional bias grid is added proximate to the patches to supply controlling voltage for the varactors. 10 K-Ohm resistors are added on the bias grid for the purpose of choking the high frequency signals on the bias grid. At the resonant frequency, the surface current flows along the inner edge of the metallic patch, and the majority of current flows through the varactor. The magnetic field forms a ring around the screen at the centre, which stores EM energy and prevents the transmitting of a plane wave. Evidently, the change of varactor capacitance would consequently tune the resonant frequency.

The resonator screen and the structure is shown in Fig. 2. In early, The original design of this patch can be traced back and it is also known as the electric-LC (ELC) resonator. The simulated structure is sensitive to steep (vertical) polarized incident wave. In this work, it is realized on a single layer FR4 board.

A very large metallic screen is required to achieve a high isolation ratio. A decoupling networks/circuits use feedback signal to cancel the coupling signal. When the signals received by antenna B are totally cancelled, high-level isolation can be realized.

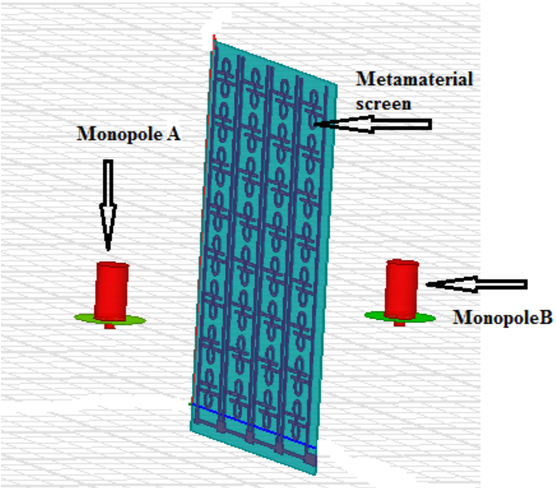
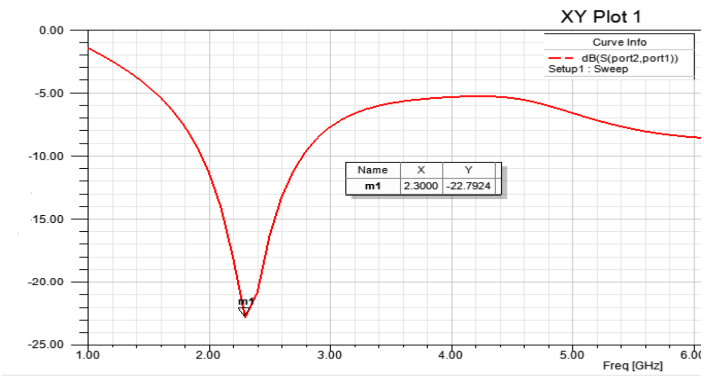


Fig: 4. proposed structure

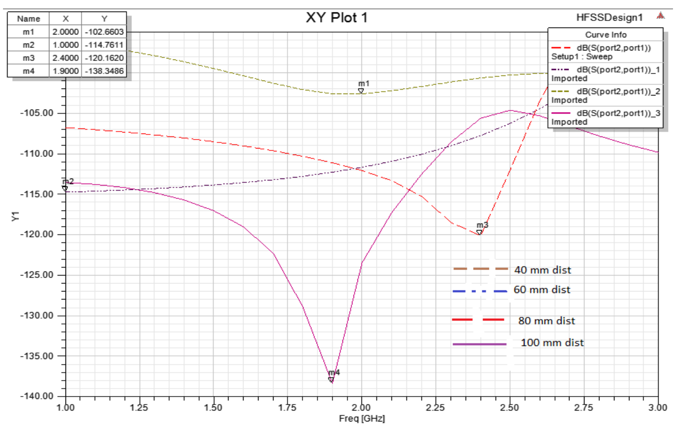
4. RESULT AND ANALYSIS

4.1. S-parameter

The resonant frequency can be tuned from 1.0 GHz to 3.0 GHz which covers the working band of the monopoles. After optimization procedure, S21 reach -138.0 dB. This result is close to the sensitivity limit of the VNA.



(a)



(b)

Fig: 5. Frequency Vs Transmission Coefficients for various distances (a) without screen, (b) metal plate (c) metamaterial screen

The direct transmission (nothing is between the monopoles) is -22.75 dB. We replace the resonator screen with a metal board having the same dimension (220 mm by 170 mm), the transmission coefficient is about -138.0 dB. Simulated results (Frequency Vs Transmission Coefficients for various distances) are shown in Fig. 5. At the frequencies, the transmission coefficients are −102.66, −114.76, −120.16, and −138.34 dB, for various distance between the antenna 4cm, 6cm, 8cm and 10cm respectively.

4.2. Radiation pattern

Radiation pattern is get from various distance between the monopole antenna A and B. fig 6. Is shown the result for the distance 4cm, 6cm, 8cm and 10cm.

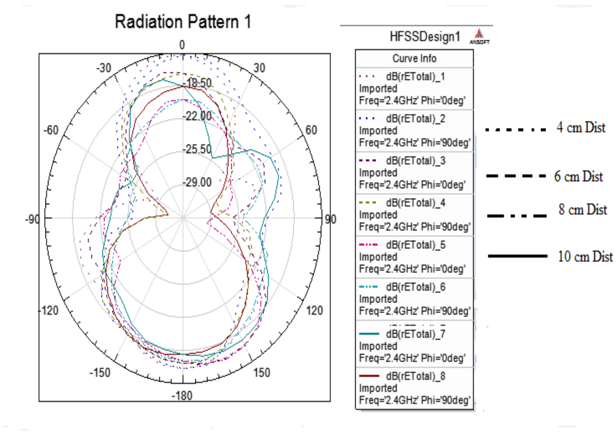


Fig : 6. Radiation pattern for proposed system at various distance.

5. CONCLUSION

The isolation enhancement of a closely-placed monopole antenna system has been achieved by using a tunable metamaterial screen structure. The results show that this method can offer a very high-level isolation during a very narrow band. Compared to other techniques, the proposed system provides good coupling suppression level for MIMO applications. This technique can be used in various areas such as MIMO antennas, two closely positioned antennas of different systems like Wi-Fi and Bluetooth, or the decoupling between transmitting and receiving antennas. In the future work we will focus on improving the band width to make this method more practical.

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