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Microstrip Antenna Array for Beamforming Systems

***Abstract**. A dual and quad element antenna array resonating at 2.4 GHz with narrow beam is proposed in this paper. An intention to put forward this work is to make use of microstrip patch antennas in beamforming to form directional beams in analog and digital domains; reducing co-channel / multipath interferences and improving Quality of Service (QoS) for senor arrays and 3G wireless networks. The size of dual and quad element antenna array is 60 x 130 mm2 and 60 x 240 mm2 respectively. Simulations in HFSS (High Frequency Structure Simulator) showed least mutual coupling among adjacent elements and prototypes have been fabricated using FR4 to verify the efficiency of the presented work for IEEE 802.11b/g WLAN standards.*

***Streszczenie.** W artykule przedstawiono dwu- i czteroelementowy układ anten o wąskim strumieniu promieniowania, o częstotliwości rezonansowej 2,4 GHz oraz możliwości wykorzystania w przesyle sygnału. (**Układ anten mikropaskowych w systemach kształtowania strumienia promieniowania antenowego**)*

Keywords: Antenna Array, Beamforming, Mutual Coupling, IEEE WLAN Standard.
Słowa kluczowe: Układ anten, kształtowanie strumienia, sprzężenie, IEEE WLAN.

Introduction

The existing trend in development of latest communication systems and wireless technologies is to achieve better coverage and capacity with high data rates [1]. Typically the power consumption and interference increases when omni directional antennas transmit signals in the directions other than the desired user [2]. Thus, the capacity can be increased by placing nulls in the direction of interferers [3]. WLAN standards offer data rates up to 54 Mbps; while GSM, CDMA and GPRS are capable of high quality voice communications but on the expense of multipath fading [4] so utilization of spatial domain (i.e. through beamforming in smart antenna systems) ensures less interference by tracking and focusing their major beam patterns to corresponding user.

The aforementioned principle is used by 3G wireless networks and they achieved the advantages of greater capacity and link quality with limited applied resources. The advance and complex signal processing algorithms made it possible to implement adaptivity [5, 6] in which each individual element of antenna is weighted separately and then its signal pattern can be dynamically adjusted [7] as initially the direction of arrival is estimated [8] and then communication is allowed only in the predicted direction ignoring all other incoming signals of the same frequency. Several arrays with directional patterns have been reported in literature [9-12].

In this paper, we present an antenna array with narrow and directive beam pattern, which is supposed to increase the performance and reduce the possible power usage, making the overall system more reliable. The array is composed of rectangular patches with modified individual ground planes. An important aspect which also comes under discussion while approximating antenna characteristics is mutual coupling, that can result due to the resonance of a single device at multiple frequencies by the antenna(s) [13]. Here, every single element is designed and positioned in a configuration that provides minimum coupling with better directivity and enhanced gain.

Design

While designing an array, the most important parameter which must be accommodate very carefully is adjustment of distance between the radiating elements of an array in order to keep it compact as well as efficient. For beamforming array the gap is calculated near λ /2, because decrement in distance creates interference and increment causes distortion, not allowing the further evaluation of received signals.

In our proposed work:

Frequency $= f = 2.4GHz$, as

$$c = f\lambda,\ \lambda = \frac{3\times10^8}{2.4\times10^9}$$

Wavelength $= \lambda = 0.122GHz$, so

$$\frac{\lambda}{2} \approx 61mm$$

A. Dual Elements Array

The two element antenna array operating at 2.4 GHz is shown in Fig.1.

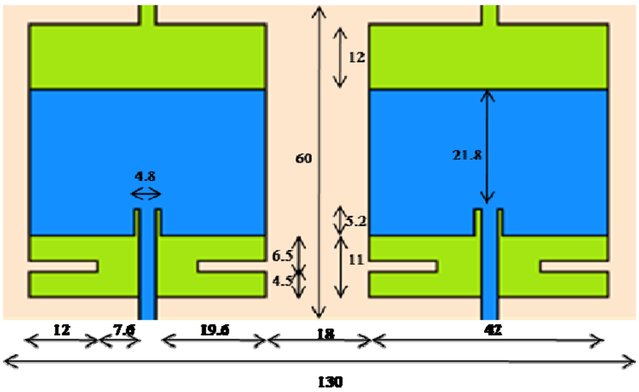


Fig.1. Dual Elements (1 x 2 linear) Array.

It consists of two rectangular patches placed side by side with an overall dimension of 60 x 130 x 1.5 mm^3 to give directive radiation pattern and maximum gain. Each element has individual ground plane to make further separation among them and is fed independently by transmission line with an impedance matching of 50 Ω. The distance between both the transmission lines is 60 mm approximately equal to the one calculated mathematically.

B. Quad Elements Array

To enhance the gain and directivity obtained from dual array, a linear quad array of 60 x 240 x 1.5 mm^3 with four feeds was simulated in HFSS and is shown in Fig.2.

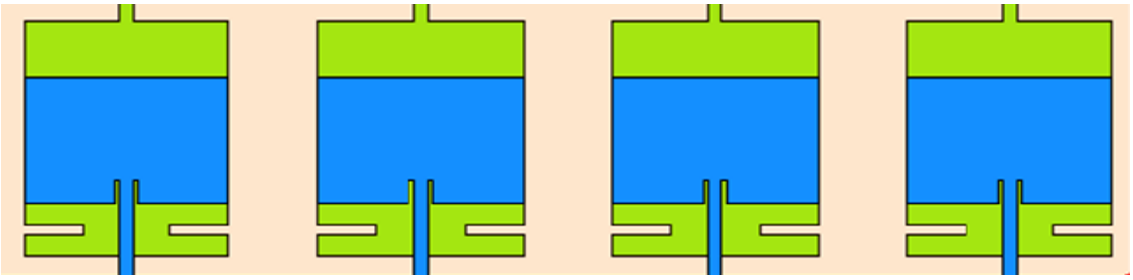


Fig.2. Quad Elements (1 x 4 linear) Array.

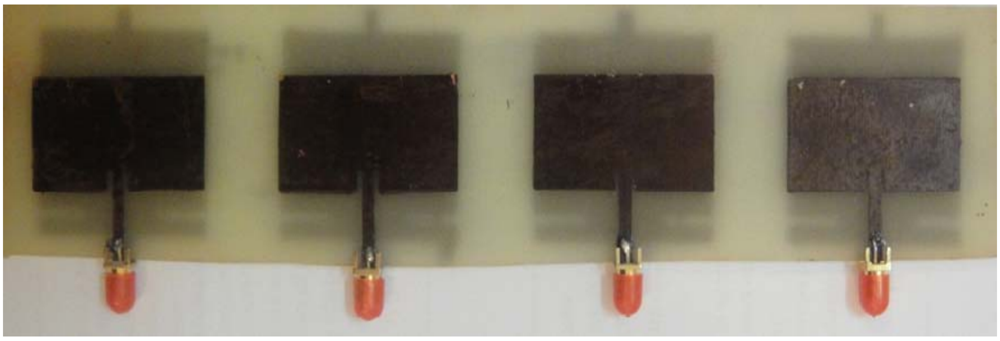
The distance between radiating elements set is 18 mm and is adjusted in such a way that the operational frequency remains at 2.4 GHz with an improved directivity and gain. Moreover, return loss is decreased from -34 to -47 dB. The fabricated arrays are shown in Fig.3 and Fig.4.

Antennas arrays are then fabricated to be sure with the performance using FR-4 as substrate having permittivity of 4.4 and are fed using SMA-connectors.

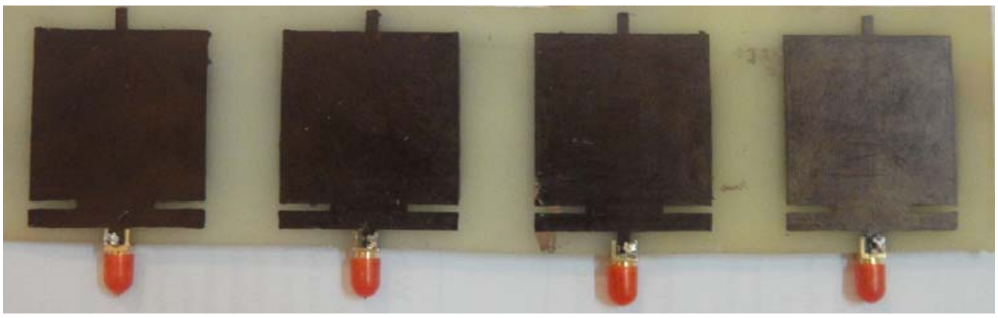
(a) Front View

(b) Back View

Fig.3. Fabricated Prototype of Dual Elements (1 x 2 linear) Array.



(a) Front View



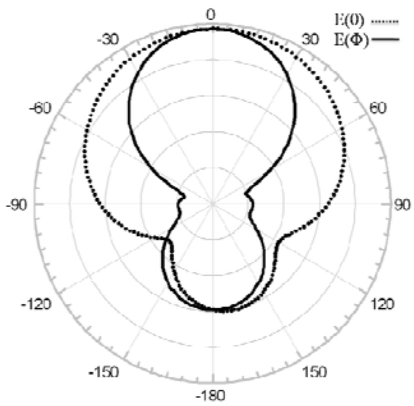
(b) Back View

Fig.4. Fabricated Prototype of Quad Elements (1 x 4 linear) Array.

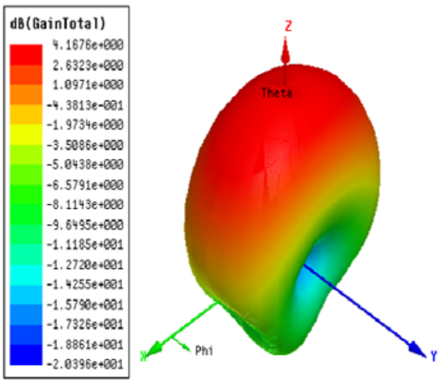
Analysis

A. Radiation Pattern / Beam Analysis

For beamforming arrays, the produced beam must be narrow and directive for precise channel formation, to focus well the object (transmitter or receiver) and place null towards the rest of the devices around (interferers). It's recommended to have high gain with least beam-width for beamforming arrays to have more range with precision of target. During formation of linear array the gap between elements and number of elements has been adjusted by considering and noticing their effect on gain and radiations.



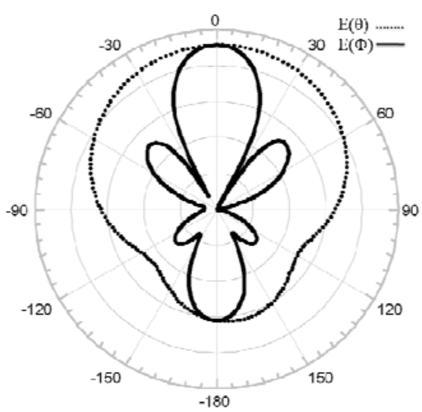
(a)



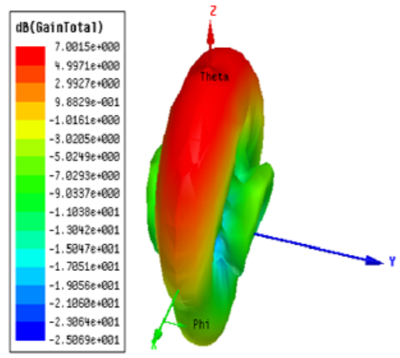
(b)

Fig.5. (a) 2D-Radiation Pattern and (b) 3D Polar Plot of Dual Element Array.

In Fig.5 and Fig.6, the radiation pattern in 2D and polar plot in 3D of 1x2 and 1x4 arrays are shown respectively at 2.4GHz. Polar-plot depict that antenna arrays have high gain in precise direction that is 4.18 and 7.00dB for 2-element and 4-element arrays respectively. By adding more radiating elements, an increment in gain is observed in a particular direction. 2D-Radiation pattern also show directive behavior but in terms of electric field in azimuth and elevation shown as E-theta and E-phi.



(a)



(b)

Fig.6. (a) 2D-Radiation Pattern and (b) 3D Polar Plot of Quad Element Array.

B. Mutual Coupling Analysis

Mutual coupling is the reason for the changes in the current distribution, which result in deformations of the radiation pattern and shows the effect of elements on each other. The performance usually degrades in MISO (Multiple-Input Multiple-Output) and SIMO (Single-Input Multiple-Output) systems, due to channel correlation. The mutual coupling between antenna elements is caused mainly by surface waves and space waves.

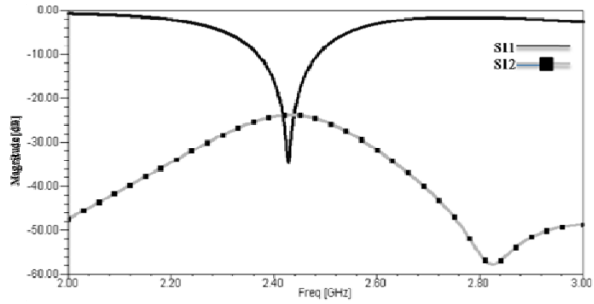


Fig.7(a). Effect of coupling on 1st element in 1 x 2 linear array.

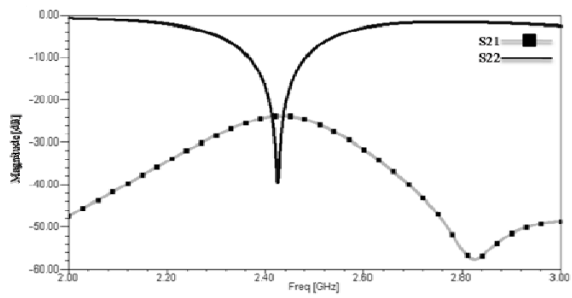


Fig.7(b). Effect of coupling on 2nd element in 1 x 2 linear array.

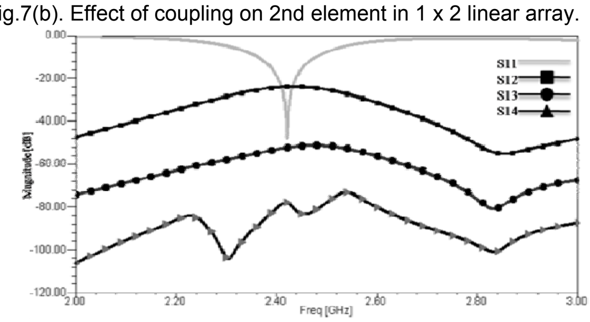


Fig.8(a). Effect of coupling on 1st element due to other elements in 1 x 4 linear array.

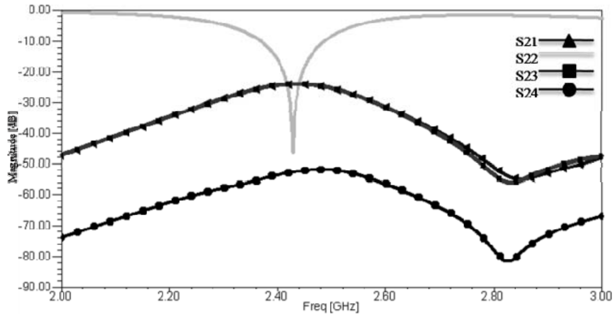


Fig.8(b). Effect of coupling on 2nd element due to other elements in 1 x 4 linear array.

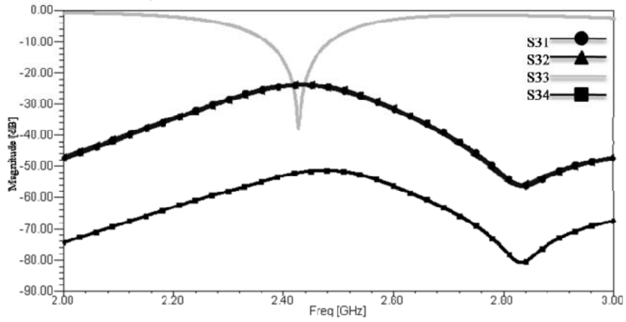


Fig.8(c). Effect of coupling on 3rd element due to other elements in 1 x 4 linear array.

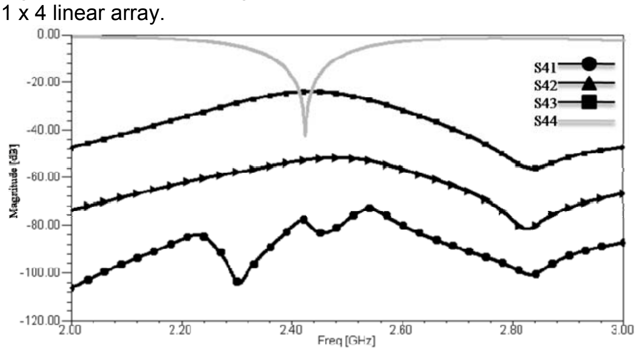


Fig.8(d). Effect of coupling on 4th element due to other elements in 1 x 4 linear array.

In our case effect of coupling is really less, avoiding interference and can be assessed by determining isolation between each element, effecting on radiations emitted by the nearby elements which can be adjusted by varying the gap between elements of an array. The results of mutual coupling are shown from Fig. 7 and Fig. 8. Results clearly show the farther the element from the other element less will be its coupling effect on other, due to the same reason the effect of element 2 on 1 is more than that of 4 or 1 in 1x 4 elements array.

Conclusion

An antenna array with ground modification, intended to transmit and receive parallel data is proposed in this paper which is applicable for IEEE 802.11b/g WLAN standards. Linear arrays of 1x2 and 1x4 are presented. Adequate coupling, isolation and return loss with sufficient bandwidth are acquired, so it can be actively considered where narrow beam and high gain antennas are required for beamforming applications. Mutual Coupling Effect and Radiation pattern has been discussed. The antenna array design is useful even for smart-antenna systems.

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