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Performance Evaluation of 64 x 64 c Node-B Antenna Beamforming for 5G Mobile System

Akam Hussein Hasan[1], Jalal J Hamad Ameen[2]
[1,2]*Electrical Engineering Department, University of Salahaddin, Erbil, Iraq*
[1]*Akamkakaka@gmail.com*, [2]*jalal.hamadameen@su.edu.krd*

Abstract— *Since the need for larger data rates and wireless system radio networks has increased, several organizations in this industry have started to develop and implement their 5G mobile technology scenarios. Since mobile telecommunications' quick expansion has motivated companies to constantly plan and work from the first generation to the fourth generation of mobile technologies. MIMO systems and beamforming antenna arrays are expected to be very important. In the 5G wireless communication systems to be utilized after 2020, when they are paired with massive MIMO systems. In this paper, the main goal is to determine the benefits of beamforming techniques in massive MIMO systems in order to increase system throughput and reduce interference, thus eliminating and resolving the various technical challenges that are presented by the implementation of massive MIMO system architectures. The goal of this work is to contribute to the development of a 5G mobile system's C-Node-B base station transceiver. The suggested design makes use of a (64 x 64 MIMO) system and optimum the beamforming technology, MIMO parameters, and the primary fundamental parameters in beamforming.*

Index Terms*: 5G mobile system, Massive MIMO, Beamforming*

I. INTRODUCTION

Any wireless network's performance will always be limited by the physical layer. This is because the amount of data that can be sent from one place to another is limited by the amount of spectrum available, the laws of electromagnetic propagation, and the principles of information theory.

There are three main things that can be done to make a wireless network work better: (I) Increasing the density of access points; (II) increasing spectrum; and (III) the ability to transmit more bits per unit of bandwidth by enhancing spectral efficiency. There will always be a requirement to maximize the spectral efficiency in a particular band, even if future wireless systems and standards employ increasingly higher access point densities and new spectral bands.

Use of multiple antennas, generally known as MIMO technology, is the only realistic way to significantly enhance spectral efficiency. MIMO's basic concept is over a century old, and directed beamforming employing an antenna array was proposed to allow more aggressive frequency reuse of restricted spectrum — in this case, very low frequency – for transoceanic communication.[1]

There are three distinct types of MIMO technology: Point-to-Point MIMO, Multiuser MIMO, and Massive MIMO, all of which were developed in different time periods. In this text, you'll learn about Massive MIMO, which is often considered to be the ultimate MIMO technique. This section explains how different MIMO variants differ from one other. The aim of this document is to provide an overview, and impact on subsequent will go into further depth on the topics addressed here.[2]

In wireless communication networks, this digital antenna delivers more diversity to the base station and/or user equipment. Reduced multipath fading and channel interference may be accomplished by utilizing beamforming methods to focus signal radiation exclusively in the predicted direction, and this radiation can then be modified to account for changes in the signal environment or shifting traffic conditions.[3, 4]

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To transfer signals from BSs with several antennas to one or more pieces of user equipment, wireless communication networks employ send and receive beamforming. By reducing the power of other users' interfering signals while raising the received signal power of each user, transmit beamforming aims to increase capacity. In order to do this, all transmitters should be sending the same signal at varying amplitudes and phase angles. Through multiple MIMO channels, the sent signal will be duplicated many times, with the aim of benefiting the intended recipients while harming the recipients of the other copies.[5, 6]

II. BEAMFORMING

A. Beamforming of Massive Mimo Antenna

It is possible to decrease interference by employing beamforming antennas rather than conventional antennas when installing a huge MIMO system with hundreds of antennas. In order to improve the capacity and performance of massive MIMO frameworks, many antenna arrays are employed to concurrently broadcast or detect many signals from various target terminals.

With an array of well-organized components, beamforming may be accomplished by only include beams that are specifically pointed at the desired destination. Massive MIMO systems' energy efficiency might be significantly improved by using a huge number of BS beamforming antenna components (BS)[7]-[9]

B. Types of Beamforming

- **Digital beamforming**

An amplitude and phase correction are made in baseband processing before transmission to the RF band. It is possible to create several beams (one for each user) from the same antenna components. MU-MIMO is digital beamforming in the LTE/5G environment. In the base station, several TRX chains are required, one for each concurrent MU-MIMO user. A digital beamforming technique called MU-MIMO is used in 5G NR. A huge number of users may submit data at the same time utilizing the same PRBs (resources for frequency and time).[6]

- **Analog beamforming**

In the radio frequency (RF) area, individual antenna signals can be shifted in their signal phases. Improved coverage may be achieved by the use of analog beamforming, this influences the antenna array's radiated pattern and gain. Digital beamforming, on the other hand, allows for the creation of only one beam per set of antenna components. By using analog beamforming, Millimeter Wave pathloss is reduced in part. Analog beamforming is therefore required for 5G New Radio (NR) systems operating in the Millimeter Wave frequency band.

- **Hybrid beamforming**

Analog and digital beamforming are used in hybrid beamforming. For 5G base station deployments, hybrid beamforming is planned to be used. MU-MIMO and SU-MIMO are two digital beamforming techniques that may be used in conjunction with analog beamforming for coarse beamforming. [10]

III. METHOFDOLOGY

A. Antenna array

The term "antenna array" refers to a collection of antennas arranged in a grid or column arrangement. It is possible to employ an antenna array for both transmission and receiving. In order to vary the gain in different directions, the signal's amplification can be varied by sending distinct copies of the same signal from each of the antennas. Instead of blanketing the whole cell with signal power,

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the signal can be focused on the intended user and even in other directions decreased to prevent interfering with other users. Another option is to employ an antenna array for reception and to increase its strength in the user's location direction in order to augment the received signal power.

In the air, electromagnetic waves mix the signals coming from several antennas. There are no major differences in transmission path lengths between the transmitting antennas and a nearby receiving device. If a single signal is transmitted by every one of these antennas, the waves will combine constructively at their receivers, even though they are located in different locations. It takes N antennas to produce a signal with N times as much amplitude as a single antenna can produce. Antenna amplitudes are, however, downscaled by one-ninth, the power increase is N over a single antenna for the same transmission power. Antenna contributions in other directions might accumulate destructively or even cancel each other completely, resulting in a zero-amplitude signal. *Fig. 1* shows how a receiving antenna transforms an incoming wave into a signal, which in turn depends on the antenna's location to determine its amplitude.[11]

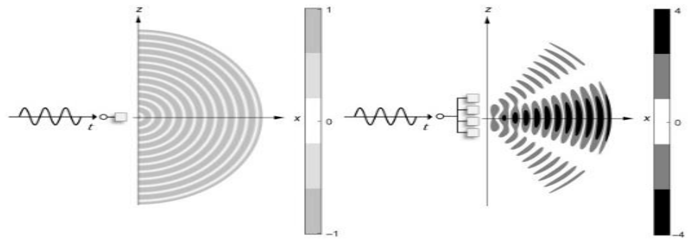

FIG. 1. ONE ANTENNA (LEFT) OR FOUR ANTENNA (RIGHT) BROADCASTASINUSOID FOR A DEFINED PERIOD AT A FIXED LOCATION IN THE XZ-PLANE (RIGHT). THE BAR LEGENDS REVEAL THE SIGNALS AMPLITUDE

B. Theoretical Design of the Suggested 5G C-Node-B Transceiver

The L length & W width of the patch antenna of *Fig. 2* is determined by the frequency of operation antenna, the dimension of the element given by [12]:

$$f = \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_r\ \varepsilon_0\ \mu_0}} \quad (1)$$

when
frequency = 1.3 GHZ and
aluminum dielectric constant ε_r = 5.4
w= 5 cm and L = 5 cm

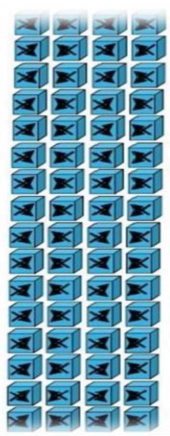

FIG. 2. PROPOSED C-NODE-B TRANSEIVER DESIGN (4X16)

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C. Practical C-Node-B Transceiver For 5G

This work has been tried to use smart antenna in a spatial design, as shown in *Fig. 3*, the gap that exists between
them =2 cm
Assume that in 64 x 64 MIMO, each antenna's width is =5 cm
The length of each antenna in 64 x 64 MIMO is assumed =5 cm
Edge of cell = 2 cm
So
We have 4 Colom's and 16 row 's
Length of the cell = 16*5 cm and the distance between
all antennas in same Colom are 30 cm and edge of the cell is 4 cm
80+30+4= 114 cm
Width of the cell = 4*5 and
the distance between all antennas in same Row is 6 cm and edge of the cell is 4 cm
= 20+6+4= 30 cm
the Result of Practical C-Node-B Transceiver (4x16) in Lab will be showing in the Table I.

FIG. 3. PRACTICAL C-NODE-B TRANSEIVER DESIGN (4x16)

D. Minimum Variance Distortion Less Response Beamforming (MVDR)

The MVDR beamforming algorithm's main idea is to decrease the differential between beam responses by choosing the weights of the antenna component while maintaining the gain level that controls the beam's path in the right direction. The method's principal goal is to reduce interference signals from unattractive directions.

The main aim of this work is to maximize the data transfer rate. A new suggested BTS design (referred to as C-Node-B in 5G) was also given after employing massive MIMO system (64x64), It aimed to eliminate interfering between all of these antennas via the use of smart antenna in spatial design and the MVDR beamforming technology.

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IV. RESULTS

A. Result of Lab Proposed C-Node-B Transceiver For 5G

TABLE I. RESULT OF PRACTICAL C-NODE-B TRANSEIVER DESIGN (4x16) IN LAB

F	$\theta 3dB$			S			ρ		
	All	V	H	All	V	H	All	V	H
1	6	142	5	1.33	1.35	1.35	0.14	0.15	0.15
1.3	18	137	10	1.23	1.24	1.25	0.1	0.1	0.1

S= VSWR
ρ= Reflection coefficient
All= All Pieces of antenna
V= 1 Piece of Antenna in Vertical
H= 1 Piece of Antenna in Horizontal

B. Result of Parameter of MVDR Beamforming Technique

The parameters of the MVDR beamforming approach have been determined and optimal for (64 x 64 MIMO) sectored into three with each having 64 antenna components, with a 2 cm space between them and a 5 cm antenna element width.

MATLAB package (2021a) has been used to simulate and optimize the parameters related to MVDR Beamforming technique using M-file codes.

Assumptions for optimization explained below:
Frequency = 1.3 GHZ
Number of antennas = 64
Zenith angle = -90, 0.1, 90
Ratio between distance and wavelength $\left({}^{d}/_{\lambda}\right)$ = 0.2
The results will show in *Fig .4* to *Fig. 11*.

A B

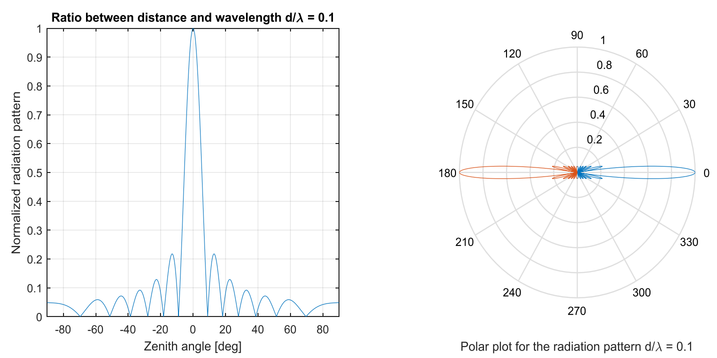

FIG. 4. (A) NORMALIZED RADIATION PATTERN WITH ZENITH ANGLE (B) RADIATION PATTERN$\left({}^{d}/_{\lambda}\right)$ = 0.1

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A B

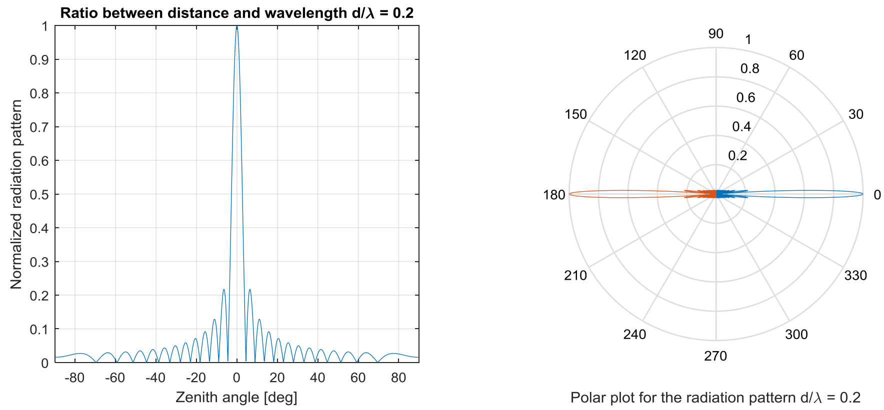

FIG. 5. (A) NORMALIZED RADIATION PATTERN WITH ZENITH ANGLE (B) RADIATION PATTERN$\left({}^{d}/{}_{\lambda}\right)$=0.2

A B

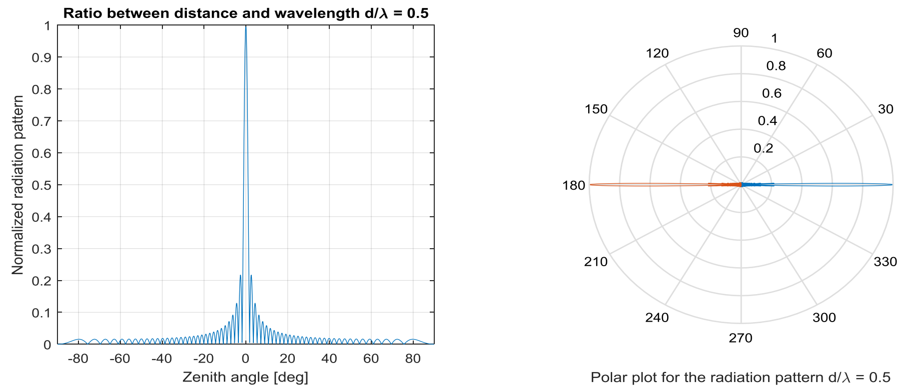

FIG. 6. (A) NORMALIZED RADIATION PATTERN WITH ZENITH ANGLE (B) RADIATION PATTERN $\left({}^{d}/{}_{\lambda}\right)$ = 0.5

A B

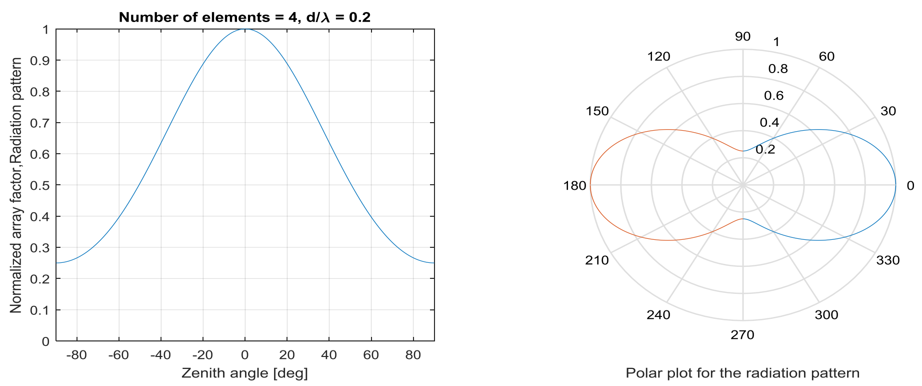

FIG. 7. (A) NORMALIZED RADIATION PATTERN WITH ZENITH ANGLE (B) RADIATION PATTERN FOR 4 ELEMENTS

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A B

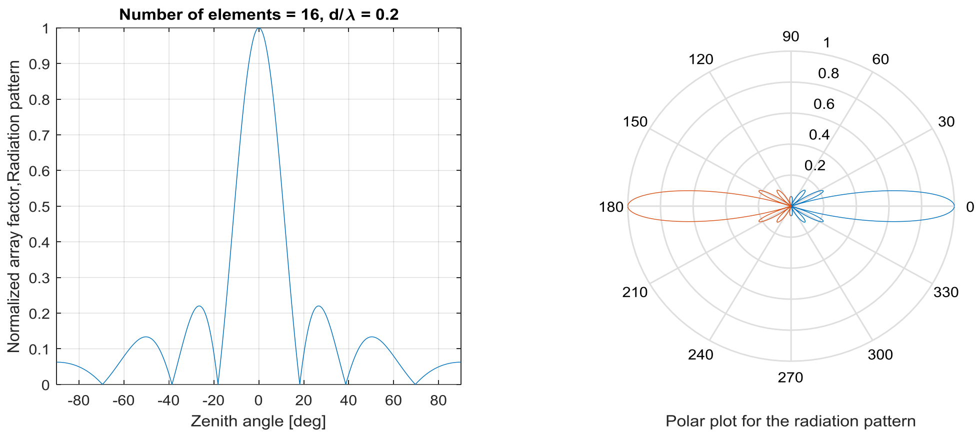

FIG. 8. (A) NORMALIZED RADIATION PATTERN WITH ZENITH ANGLE (B) RADIATION PATTERN FOR 16 ELEMENTS

A B

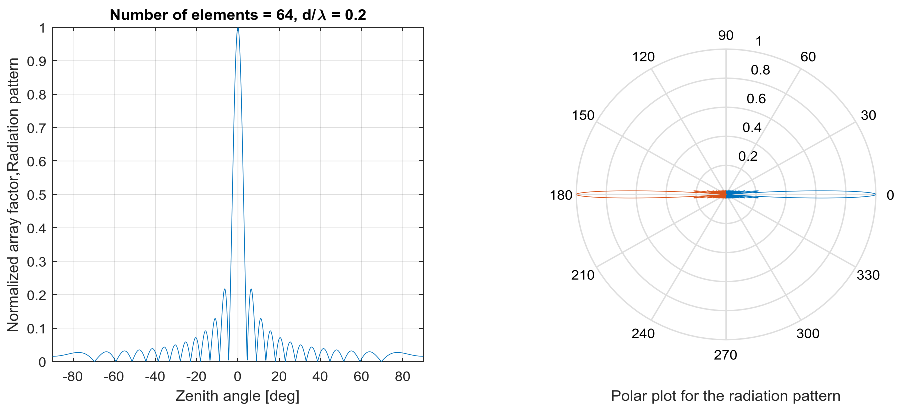

FIG. 9. (A) NORMALIZED RADIATION PATTERN WITH ZENITH ANGLE (B) RADIATION PATTERN FOR 64 ELEMENTS

A B

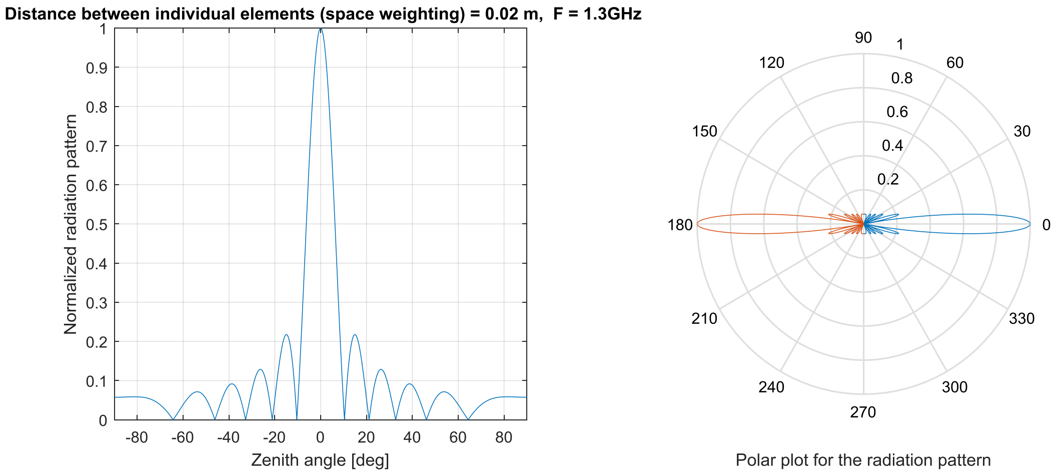

FIG. 10. (A) NORMALIZED RADIATION PATTERN WITH ZENITH ANGLE (B) RADIATION PATTERN FOR DISTANCE BETWEEN ELEMENT PATCHES ARE 2 CM AND F=1.3GHZ

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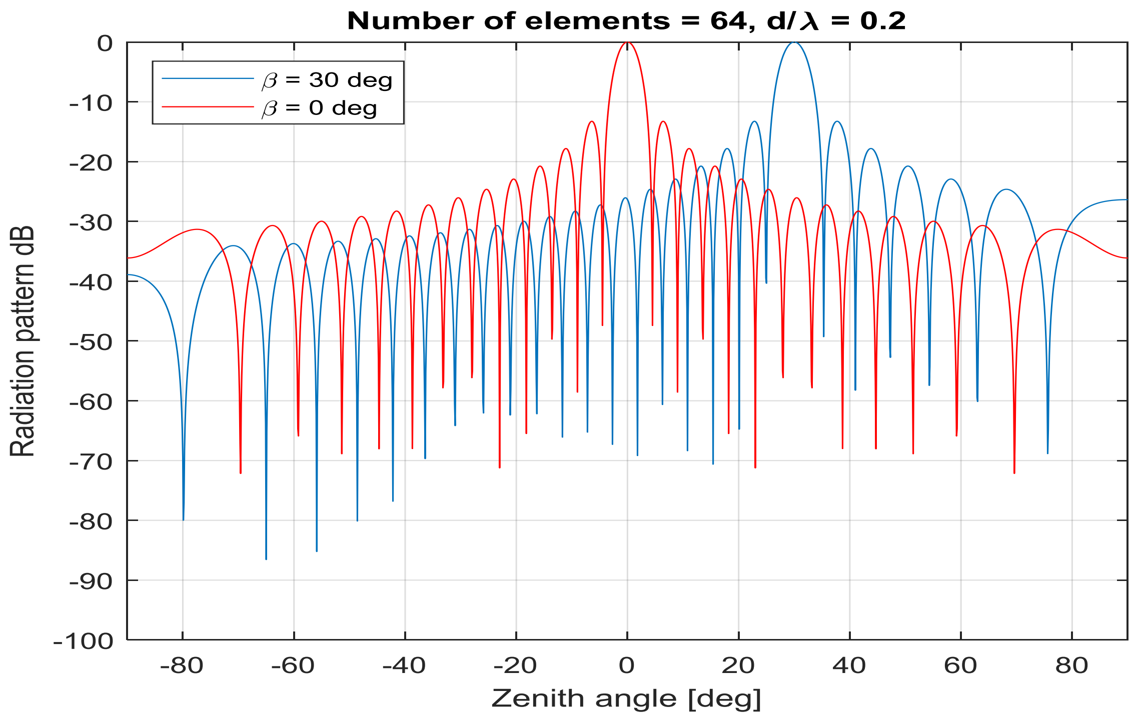

FIG. 11. RADIATION PATTERN AS A FUNCTION WITH ZENITH ANGLE WHEN NUMBER OF ELEMENTS = 64 AND $\left({}^{d}/_{\lambda}\right) = 0.2$

V. CONCLUSIONS

This paper is an effort to contribute in this sector in order to improve the performance of 5G, as shown in the results, by using massive MIMO (64 x 64) system The Suggested design for antenna beamforming will enhance several important characteristics, it was found that increasing the number of elements reduced the size of the main lobe. The (5G) is the combination of mobile frameworks. There are a few issues that need to be solved during the works in this system. Fifth generation (5G) is the integration for another mobile framework. As shown in the results in *Fig. 4*, *Fig. 5* and *Fig. 6* when we used the $\left({}^{d}/_{\lambda}\right) = 0.2$ the antenna has a best result compare with $\left({}^{d}/_{\lambda}\right) = 0.1$ and $\left({}^{d}/_{\lambda}\right) = 0.5$, and we see in *Fig. 7*, *Fig. 8* and *Fig. 9* when we increase the number of elements, we see that we have the best result and as shown in *Fig.10* when distance between element patches are 2 cm and F= 1.3 GHZ we have a good result also, in *Fig. 11* we see that our Proposed C-Node-B Transceiver Design have a result that prove our idea when we increase the number of elements the main lobe area will decrease these results by decreasing the interference and increasing the performance of system.

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