A compact 5G antenna printed on manganese zinc ferrite substrate material

Ashiqur Rahman\textsuperscript{1a)}, Ng M. Yi\textsuperscript{1}, Afaz U. Ahmed\textsuperscript{1}, Touhidul Alam\textsuperscript{1}, Mandeep J. Singh\textsuperscript{2}, and Mohammad T. Islam\textsuperscript{2b)}
\textsuperscript{1} Space Science Centre, Universiti Kebangsaan Malaysia, Bangi, Selangor, 43600, Malaysia
\textsuperscript{2} Department of Electrical, Electronic and Systems Engineering, Universiti Kebangsaan Malaysia, Bangi, Selangor, 43600, Malaysia
\textsuperscript{a)} ashiqur@siswa.ukm.edu.my
\textsuperscript{b)} tariqul@ukm.edu.my

Abstract: In this article, a compact antenna is proposed using new microwave dielectric ceramic (MDC) substrate for 5G millimetre wave application. The distinctive novelties exhibited in this article are used of MDCs substrate material for antenna designing and performances analysis for wireless communication. The proposed antenna achieves impedance bandwidth of 2.66 GHz (from 27.235 GHz to 29.895 GHz), which covers the top interest (28 GHz) for 5G mm-wave in some countries and trials have been reported. The proposed antenna attains average gain of 5.44 dB and 93\% of radiation efficiency with antenna size of $1.32\lambda \times 1.32\lambda \times 0.094\lambda$.

Keywords: Microwave Dielectric Ceramic, Manganese zinc ferrite substrate, Sol-gel method, 5G antenna

Classification: Electron devices, circuits and modules

References

[1] N. Ranjkesh, et al.: IEEE Antennas Wireless Propag. Lett. 13 (2014) 1425 (DOI: 10.1109/LAWP.2014.2341172).
[2] C. Huang and Y.-M. Tseng: IEEE Trans. Dielectr. Electr. Insul. 21 (2014) 2293 (DOI: 10.1109/TDEI.2014.004074).
[3] Y. Li and K.-M. Luk: IEEE Access 3 (2015) 274 (DOI: 10.1109/ACCESS.2015.2420103).
[4] W. Fang, et al.: European Microwave Conference (EuMC) 44th (2014) 1636 (DOI: 10.1109/EuMC.2014.6986767).
[5] J. Wu and K. Sarabandi: Radio Science Meeting (Joint with AP-S Symposium), USNC-URSI (2014) 111.
[6] M. Vural, et al.: J. Mater. Chem. C Mater. Opt. Electron. Devices 2 (2014) 756 (DOI: 10.1039/C3TC32113D).
[7] T. Cai, et al.: IEEE Trans. Antennas Propag. 63 (2015) 2306 (DOI: 10.1109/TAP.2015.2405081).
[8] H. Mosallaei and K. Sarabandi: IEEE Trans. Antennas Propag. 52 (2004) 1558 (DOI: 10.1109/TAP.2004.829413).
[9] F. Sultan and S. S. I. A. Mitu: Loughborough Antennas and Propagation Conference (LAPC) (2014) 427 (DOI: 10.1109/LAPC.2014.6996416).
1 Introduction

Within the industry and academia, there is a significant activity in research and development towards the identification of the frequency bands required to deliver the next generation mobile broadband services. It is widely accepted that at least fifth generation of mobile communication will need the use of spectrum bands at much higher frequencies than those that current mobile broadband technologies can make use of. Millimetre (mm) wave communication is the most promising way to alleviate the spectrum scarcity at lower frequencies and provide high bandwidth communication channels. In last few years, declaration from some renowned cellular phone companies of the world dragged interest internationally towards some frequency bands. Samsung, a multinational conglomerate company has already tested the performance of mm Wave communication in 800 MHz bandwidth at 28 GHz. Some other companies like Nokia, Intel and METIS EU project have also shared their interest on 28 GHz. Along with the higher frequency range, the interest also comes down to the new antenna technology with new substrate, dynamic structure, adaptive array configuration, long term performance, low cost and eco-energy friendly operation etc. In this article, a compact rectangular shaped printed antenna has been presented for mm Wave application. The antenna is printed on manganese zinc ferrite substrate (Mn0.2Zn0.8Fe2O4) substrate that has low loss properties (loss tangent $\varepsilon$). The article aims to introduce a new dielectric substrate to construct a compact antenna for 5G mm wave application.

In recent days, new dielectric substrate antenna construction has been in focus to maximize the performance of antenna in 5G communication. And so far planner antenna has been highly recommended in all trails for such mm wave communication. In article [1], a high-efficiency tapered dielectric antenna is proposed that is designed and fabricated on a new integrated technology platform called silicon-on-glass (SOG). The antenna is fabricated using photolithography and dry etching of the Si layer of the SOG wafer. A new triple-band dielectric resonator antenna fed by a coplanar waveguide is presented in article [2]. A water dense dielectric patch antenna was proposed in the article [3]. In another research [4], a wideband millimetre-wave antenna is found which is developed using dielectric rod antenna. In many studies, magneto-dielectrics are also getting priority in planner antenna designs [5, 6, 7]. Magneto-dielectrics for antenna design has few advantages was discussed in article [8]. Use of ferrite-dielectric is also been a practice in some previous studies [9, 10].

In this paper, a new sol–gel method based synthesized MDCs substrate material is introduced for mm wave antenna design. The antenna performances are experimentally validated with simulated results.
2 Methodology

The Mn_{0.2}Zn_{0.8}Fe_{2}O_{4} nanoparticle powder has been synthesized using sol–gel method and prepared microwave dielectric ceramics (MDCs) substrate material for antenna fabrication. The dielectric constant and quality factor of the proposed material have been measured with an LCR meter (HP 4284A) for 20 Hz to 1 MHz at room temperature. The dielectric constant and loss tangent are measured 7.0 and 0.003, respectively. The antenna patch and ground plane of the proposed antenna has been coated with silver using a silver target by magnetron sputtering as shown in Fig. 1. The antenna is consists of a rectangular radiating patch connected with 50 $\Omega$ microstrip feed line in the top side and a full ground plane in the bottom side.

3 Results and discussion

The optical band gap for the absorption peak was determined by extrapolating the linear portion of the plot of Fig. 2 to $a = 0$. The obtained value was 1.5 eV for Mn_{0.2}Zn_{0.8}Fe_{2}O_{4}, revealing a semiconductor behaviour. However, there is not much information about the bandgap value of MnFe_{2}O_{4} particles except at a study performed by GuO et al., the bandgap values are given as 1.68 eV and 1.74 eV for hollow spheres and colloidal nano crystal cluster respectively [11].

![Fig. 1. Geometric layout of proposed antenna](image)

![Fig. 2. Tauc plot to determine optical bandgap from UV-Vis absorption spectrum.](image)
Fig. 3 shows the field emission scanning microscope analysis (FESEM) micrograph that explored qualitative surface morphology of the microstructure of (Mn$_{0.2}$Zn$_{0.8}$Fe$_2$O$_4$) samples sintered at 850°C for 2 h. The instrument shows the grain growth of the new crystallization and nucleation which resulted the formation of fine particulates. The sample appear to consist of some regular grains with a narrow distribution of grain sizes. The films have the cubic symmetry of a spinel structure in the form of regular octahedral.

![FESEM micrograph of Mn0.2Zn0.8Fe2O sample annealed at 850°C](image)

The reflection coefficient of the proposed antenna has been measured using performance network analyser (PNA). The measured and simulated reflection coefficient of the proposed antenna is illustrated in Fig. 4. It is observed from Fig. 4 that, the antenna achieved $-10$ dB reflection coefficient of 2.66 GHz (27.235–29.895 GHz). There is a small deviation is observed between measured and simulated reflection coefficient due to fabrication tolerances. The radiation efficiency and realized gain of the proposed antenna has been analysed, presented in Fig. 5. The antenna achieved average 93% of its efficiency within entire operating band. The maximum realized gain is achieved at 28 GHz, which is about 5.82 dB.

![Reflection coefficient of the proposed antenna](image)
The radiation pattern of the proposed antenna is illustrated in Fig. 6. Fig. 6 shows the measured radiation patterns of the proposed antennas in two principal planes—namely, $E$ (XZ) and $H$ (XY) planes for resonant frequency at 28 GHz. A pattern taken in any plane containing z-axis is called an $E$-plane; because it is parallel to the electric field vector $E$. On the other hand, a plane pattern taken in a plane orthogonal to an $E$ plane and cutting through the short dipole antenna is called an $H$-plane pattern, because it contains the magnetic field $H$. The radiation patterns have been measured in an anechoic chamber using far field antenna measurement system and Agilent E8362C PNA Network Analyzer. A near omnidirectional radiation pattern for co-polarization is observed in the $E$ plane. Ripples can be observed in both $E$- and $H$-planes owing to the generations of higher-order resonant modes. The cross polarization components increase in $H$-plane due to the increase in orthogonal surface currents.

4 Conclusions

In this paper, a novel microwave dielectric ceramics based microstrip antenna is presented for possible fifth generation mm wave wireless applications. Possible real life implementable multi-standard mobile antenna, which can make new research scope for synthesized dielectric material for microwave applications.

Acknowledgments

This work is supported by the Ministry of Education Malaysia (MOE) under grant no FRGSTOPDOWN/2014/TK03/UKM/01/1. Communication Technology Division, Ministry of Post, Telecommunication and Information Technology, Dhaka, Bangladesh