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A Compact Penta-Band Low-SAR Antenna Loaded with Split-Ring Resonator for Mobile Applications

M. Manikandan [1] and S. Karthigai Lakshmi [1]

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Abstract

A compact rectangular patch with dual-ring SRR (split-ring resonator) is presented in this article. An antenna is designed on FR4 substrate with an overall footprint size of 26 mm × 30 mm × 1.6 mm. The antenna presented operates in five bands from 2.95 to 3.06 GHz, 3.79 to 3.87 GHz, 4.11 to 4.19 GHz, 5.39 to 5.51 GHz, and 5.97 to 6.11 GHz. Mobile and fixed voice communication, WiMAX (Worldwide Interoperability for Microwave Access), 5G (5th generation), WLAN (Wireless Local Area Network), and ISM (Industrial Scientific and Medical) are some applications that utilized the above resonating bands. The penta-band operation is due to the inclusion of dual-ring SRR. The optimum values of the critical parameter of the SRR are identified using parametric analysis, and the results are presented. The antenna is also analyzed for the SAR (specific absorption rate) values, and it was found to be less than 2 W/kg for 10 g volume of tissue. The designed antenna is fabricated and tested, and the presented results show that there is good agreement between the simulated and measured results. Penta-band operation with simple structure, stable radiation pattern, and low SAR makes this antenna more intelligent and suitable for the mobile application.

1. Introduction

The major requirement of modern wireless personal communication devices like smart phones in the past two decades is antenna, which exhibits multiband frequency of operation, omnidirectional radiation pattern, and low SAR. Bluetooth, WLAN, Satellite Communication, LTE (Long-Term Evolution), 4G (4th generation), 5G (5th generation), WiMAX, RFID (Radio Frequency Identification), etc. are some of the wireless standards [1] which are the essential frequency ranges needed to be incorporated in modern wireless personal communication devices like mobile phones. These devices allow only a limited space for antenna integration. This leads to another challenge for the antenna researchers to achieve the compactness of the structure. There are a variety of antenna techniques that support multiband characteristics, and the primary advantage of using the multiband antenna is that it reduces the size and complexity of the system, as a single antenna is capable of satisfying all the applications. It also eliminates the filters in the system, which results in reduced complexity, fabrication difficulty, cost, and installation requirements. The microstrip patch antenna can easily achieve such requirements [2–5] due to its low-profile characteristics.

Another essential parameter needed to be reduced in mobile device is SAR. The value of SAR in mobile phone antenna must be within the limit. According to ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines, maximum SAR value should be 2 W/kg averaged over any 10 g volume of tissue [6], and according to the guidelines given by US FCC (Federal Communication Commission), it should be 1.6 W/kg averaged over any 1 g volume of tissue [7]. The high SAR mobile phone causes many biological effects on human body such as irreversible infertility, DNA damage, brain tumor, and so on. There are many antenna structures adopted ever since the formation of the first generation of mobile communication to reduce the SAR value. Along with main antenna structures, supplementary elements like conducting materials [8], reflector [9], ferrite shielding [10], directional antennas [11], and resistive cards [12] are added to reduce the SAR value. Even though the above supplementary elements reduce SAR at greater level, they will improve product cost and size. The other essential parameters, such as gain, radiation efficiency was not up to the required level for above structures and also lagging in resonating with multiple frequencies. By considering these limitations, many researchers recently focused to modify the main antenna structure instead of adding supplementary elements. The AMC (artificial magnetic conductor) structure [13, 14] will reduce the SAR value and improve gain by using high impedance surface property during operating frequency. But it requires additional space and does not support multiband of operation. The SAR value can also be reduced by optimizing electric [15] and magnetic field [16]. But there is no evidence of improving gain and increasing operating bands by using this technique. The EBG (electromagnetic band gap) structure [17–19] will suppress the surface waves which will improve radiation efficiency and gain. While exhibiting stop band characteristics, it behaves like AMC structure that redirects all the radiation opposite to human head which in turn reduces the SAR value. The structure can be further optimized by reducing the size and improving return loss values. Reducing SAR without affecting antenna parameters is a challenging task.

Metamaterials are termed materials which have several distinct properties like negative permittivity and negative permeability [illegible]. These distinct properties play a major role in designing high performance antenna especially for exhibiting multiband operation [illegible] and reduce SAR at greater level [illegible]. The most common metamaterial structures widely used are SRRs (split-ring resonators) [illegible] and CSRRs (complementary split-ring resonators) [illegible]. SRR may consist of two concentric split rings which act as resonators facing in opposite direction. The shape of the rings is not restricted to ring or circle structure [

Dr. D. SENTHIL KUMARAN, M.E., Ph.D., (NUS)
Principal
SSM Institute of Engineering and Technology
Kuttathupatti Village, Sindalagundu (Po),
Palani Road, Dindigul - 624 002.

SSM Institute of Engineering and Technology • DINDIGUL-624 002 •
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