DUAL BAND MONOPOLE ANTENNA WITH HARMONIC SUPPRESSION CAPABILITY

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A project report thesis submitted in partial fulfillment of requirement of the award of the Master’s Degree Electrical Engineering

Faculty of Electrical & Electronic Engineering
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JULY 2018
“Special dedication to my beloved family members and all my dearest
Brothers and Sisters"
ACKNOWLEDGEMENT

In the name of Allah most Gracious and most Merciful

First and foremost, I would like to extend my greatest thanks the almighty Allah, the creator for everything who gave me this opportunity of education here in Malaysia.

Second I would like to express my highest thanks of gratitude to my respectful supervisor, DR. NOORSALIZA BINTI ABDULLAH for his support and encouragement during this project. At many stages in the course of this research project I benefited from his advice, particularly so when exploring new ideas. Her positive outlook and confidence in my project inspired me and gave me confidence. Her careful editing contributed enormously to the production of this thesis.

Last but not least I would to convey a heartfelt my parent Special appreciation to my beloved father Mohamed Abdirahman Jama, brothers, sisters, and other family members including my uncle, ants and their families, their prayers and to give me unforgettable encouragement is gratefully appreciated.

Thank you all for your kindness and generosity. May Allah bless everyone.
ABSTRACT

Growing communication industry have overstated the demand for high performance multi-purpose antenna systems. Monopole antenna are well known for their compact size and low profile applications. The use of GSM and the ISM band frequencies at the same time by different devices require multiple antenna to support more than two frequencies. Thus this states the requirement and demand for antenna with multiple frequencies of operation and capability. However different dual band antennas also suffer from harmonic generation and higher order resonances. Due to these higher order resonances electromagnetic interference and noise increases and thus they bring down the performance of communication systems. In order to address the problem this research proposes a dual band operation with a Monopole antenna for GSM and ISM band of operation. The antenna resonates at 0.9 MHz for GSM band and 2.4 GHz for ISM band. The antenna was simulated using CST MWS. The proposed antenna was having a dual band operation with harmonics in the higher order bands. In order to reduce the harmonic of the antenna. The stub loaded feed line was proposed. Three different length stubs were attached with the antenna feed line in order to suppress the harmonics on the patch antenna. A thorough investigation was carried out for the harmonic suppression below – 10 dB level. The antenna was fabricated above FR-4 based epoxy substrate material. Scattering parameter measurements were performed using vector network analyzer. The comparison of results shows a good agreement between the measured and the simulated results. It has been demonstrated that the proposed antenna design configuration shows dual resonance at 0.9 and 2.40 GHz for GSM and ISM bands at total efficiencies above 80%. Moreover, the application of stubs attached to the feed line the harmonics suppression has been achieved below -10 for the frequency band of 3 -10 GHz.
ABSTRAK

Industri komunikasi yang semakin berkembang dengan sistem antena pelbagai guna yang berprestasi tinggi telah menghasilkan permintaan tinggi. Antena monopole terkenal dengan saiz yang lebih kecil dan kos yang rendah. Penggunaan frekuensi band GSM dan ISM pada masa yang sama oleh peranti yang berlainan memerlukan antena berganda untuk menyokong lebih daripada dua frekuensi. Oleh itu, ini menyatakan keperluan dan permintaan antena dengan pelbagai kekerapan operasi dan keupayaan. Walau bagaimanapun antena jalur ganda yang berbeza juga mengalami generasi harmonik dan gangguan yang lebih tinggi. Oleh kerana gangguan elektromagnetik dan peningkatan bunyi yang lebih tinggi dengan itu telah menyebabkan penurunan prestasi sistem komunikasi. Untuk menangani masalah ini penyelidik mencadangkan operasi dua jalur dengan antena Monopole untuk operasi GSM dan ISM. Antena bergema di 0.9 MHz untuk band GSM dan 2.4 GHz untuk band ISM. Antena disimulasikan menggunakan CST MWS. Antena yang dicadangkan itu mempunyai operasi dual band dengan harmonik di band pesanan yang lebih tinggi bagi mengurangkan harmonik pada antena. Barisan suapan yang dimuatkan stub telah dicadangkan. Tiga stubs panjang yang berbeza dipasang dengan garis suapan antena untuk menekan harmonik pada antena patch. Siasatan menyeluruh dilakukan untuk penindasan harmonik di bawah - tahap 10 dB. Antena dibuat di atas material substrat epoksi FR-4. Pengukuran parameter pengukuran dilakukan menggunakan penganalisis rangkaian vektor. Perbandingan daripada hasil ujikaji dan simulasi telah menunjukkan keputusan yang sangat baik. Demonstrasi terhadap reka bentuk antena yang dijalankan menunjukkan gangguan frekuensi dwi pada 0.9 dan 2.40 GHz untuk band GSM dan ISM pada jumlah kecekapan melebihi 80%. Selain itu, penerapan stubs yang dilampirkan kepada garis suapan penindasan harmoni telah dicapai di bawah -10 untuk band kekerapan 3 -10 GHz.
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<td>LAN</td>
<td>Local Area Network</td>
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<tr>
<td>RF</td>
<td>Radio Frequency</td>
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<td>HSA</td>
<td>Harmonic Suppression Antenna</td>
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<tr>
<td>AIA</td>
<td>Active Integrated Antenna</td>
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<tr>
<td>OCS</td>
<td>Open Circuit Stub</td>
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<tr>
<td>DGS</td>
<td>Defected Grounded Structure</td>
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<tr>
<td>CST</td>
<td>Computer Simulation Technology</td>
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<tr>
<td>HOM</td>
<td>Higher Order Mode</td>
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<td>HAS</td>
<td>Harmonic Antenna Suppression</td>
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<tr>
<td>EM</td>
<td>Electromagnetic</td>
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<td>VSWR</td>
<td>Voltage Standing Wave Ratio</td>
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<td>SWR</td>
<td>Standing Wave Ratio</td>
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<td>EBG</td>
<td>Electromagnetic Band Gap</td>
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<tr>
<td>ISM</td>
<td>Industrial Scientific and Medical</td>
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<tr>
<td>GSM</td>
<td>Global System for Mobile Communication</td>
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<tr>
<td>CPW</td>
<td>Coplanar Waveguide</td>
</tr>
<tr>
<td>SAR</td>
<td>Specific Absorption Rate</td>
</tr>
<tr>
<td>DCS</td>
<td>Distributed Control System</td>
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<tr>
<td>PCS</td>
<td>Personal Communication Service</td>
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<tr>
<td>PIFA</td>
<td>Planar Inverted-F Antenna</td>
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<td>MWS</td>
<td>Microwave Studio</td>
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<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>UN Light</td>
<td>Ultraviolet</td>
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<tr>
<td>PRS</td>
<td>Partially Reflective Surface</td>
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CHAPTER 1

INTRODUCTION

1.1 Background study

Electromagnetic waves are transmitted and received via electrical devices known as antennas. Antennas play the role of intermediate devices that convert the electrical signals in the wire into wireless waves that can propagate in free space and vice versa. Antenna find versatile applications in the area of radio communication and are used with different designs and forms depending upon application and requirements. The transmitted signals from the antenna are absorbed by the concrete walls, rocks and other hurdles in between the transmission path. Antenna can be used for applications such as the television or radio broadcasting, communication between two remote points, WLAN, GSM applications, space borne platforms and different types of radar systems. Usual antenna systems are employed in open environments for better radiation efficiencies. However, they are also employed under water and underground applications at shorter wavelength with special purposes. On the basis of pattern directionality there are two categories of antennas; parallel to ground level patterns (horizontal plane) and pattern parallel to vertical plane (ground plane perpendicular) [1].

Communication between two devices at a distance is practically impossible with wired connections. So the use of antennas for wireless communication is a necessity for distant communication. The term wireless communication is vastly used in the telecommunication industry where it refers to communication between radio transmitters and receivers, remote controls and different networked units. They utilize different types
of modes of communication such as visible light, infrared or acoustic signals. This makes the communication possible between two distant nodes without wired connections. These may include various types of communications such as communication between two points, between multiple points, broadcasting, and unicasting. IEEE states a standard definition for antenna systems as “a means for radiating or receiving radio waves” (IEEE Std 145-1983). Thus it is an effective device or structure that enables waves to radiate out of wires to the free space and vice versa. In addition to other properties, antennas also exhibit the property of reciprocity. The behavior is stated as showing or maintaining the same characteristics no matter antenna is in receiving or transmitting state.

The technology of monopole antenna allows the antenna design with the small size and provides wideband performance while maintaining the radiation efficiency. The presence of undesired higher frequencies in the system results in increasing the noise floor of the system and would increase the system complexity will in the use of noise filters. Harmonic trap antenna is another feasible solution for this problem where the noise can be eradicated at the input level of communication system. Different types of harmonic suppression antenna have been reported in the literature. Microstrip antenna provide on the key benefits in terms of ease of integration with the electronics and power amplifiers at the RF frontend. Thus with this advantage they can be easily make the electronics more compact and easy to mass produce including antenna such as the active integrated antennas (AIA). However, the current AIA antenna suffers problems of harmonics and the harmonics present result in rising the noise floor of the RF frontend. Thus the undesired harmonics need to be suppressed. Different techniques for this problem has been reported in the literature such as the open circuit stubs (OCS) and defected ground planes (DGS). The stated methods can be using with any types of antennas [2].

1.2 Problem statement

Modern wireless electronic devices require multiple frequencies for communication and operation along with requirement of smaller physical size for shrouded space and microelectronics. Dual band applications require compact and miniaturized efficient antenna. A monopole antenna with dual band is an excellent candidate for dual band
application. However, the undesired generation of harmonics due to higher order modes (HOM) in the antenna results in undesired noise and bandwidth consumption in radio antenna systems.

To overcome the problem, some technique of harmonic traps can be used to prevent an electromagnetic interference and reduce the spurious harmonic radiation of patch antenna such as OCS, EBG and DGS. Besides that, patch antennas are known for their light weight, low volume and low fabrication costs. Therefore, an antenna with harmonic traps can be designed using any suppression technique to ensure the disturbance of electromagnetic can be solved and also reduced either size or cost of proposed antenna.

1.3 Objective of this study

The objectives of the research are stated below:

1. To design monopole antenna with harmonic suppression capability at 0.9 and 2.40 GHz for wireless communication systems.
2. To simulate the dual band monopole antenna using Computer Simulation Technology (CST).
3. To fabricate and validate the simulation results with experimental results.

1.4 Scope of study

In order for a smooth and sequential flow of the research work different milestones and steps were defined for project. The significant scopes outlines are listed below.

1. Different types of micro-strip antennas are available for different applications. This project covers focuses on dual band monopole antenna. The designed antenna would be required to achieve dual band operation.
2. Design and modelling of a dual band monopole antenna for operational frequency of 0.9 - 2.4 GHz. The frequency range used for the analysis of harmonic suppression is between 2 – 10 GHz.
3. The dual band monopole antenna with stubs to suppress higher order mode (HOM) will be designed and modelled using CST MWS.

1.5 Thesis outline

The thesis document has been divided into different chapters and modules depending upon the milestones of the research work. The thesis consists of five chapters. The first chapter consists of introduction, background and the problem statement of the research. The chapter also highlights the objectives and the scopes of the research. Chapter 2 contains the literature studies of the research work. Different techniques and background studies of different researchers are provided in this chapter. Chapter 3 presents the project methodology and the work flow of the project. The fabrication methodology, simulation design scheme and the measurement setup are being discussed in detail. Chapter 4 presents the comparison of results and comparison of simulated and measured results. Detailed discussion on different simulation results is presented in this chapter. Chapter 5 presents a brief discussion on the conclusive remarks along with the future works and the potential recommendations of research work.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides insight overview about the monopole antenna and antenna properties, harmonic suppression antenna and its techniques, advantages and disadvantages of monopole antennas, the previous research on designing antenna with harmonic suppression (HAS).

2.2 Antenna properties

2.2.1 Operating frequency

An antenna is designed to work efficiently at some frequency range. The antenna can meet its all design specifications at certain range of frequencies. The design specifications are dependent upon the design and size of the antenna. The size of the antenna is directly related to the operational wavelength. Thus the antenna is tuned by controlling the electrical length of the antenna.
2.2.2 Return loss

The return loss of an antenna is the ratio of amplitudes of reflection wave and incident wave. The return loss is calculated at the input terminal of the antenna. It gives information about the amount of energy absorbed in the antenna load and the amount of energy that is rejected by the antenna. Thus a smaller value of return loss is always desired. Figure 2.1 and also return loss can be expresses as Equation 2.1.

\[ \text{Reflection loss} = 20 \log \frac{Z_1 + Z_2}{Z_1 - Z_2} \]  (2.1)

Where

\( Z_1 = \) impedance toward the source
\( Z_2 = \) impedance toward the load

2.2.3 Voltage standing wave ratio (VSWR)

The impedance of the antenna is defined as the hindrance for the incoming energy from the generator to the load. The antenna acts as a load for the incoming signal. Thus the impedance of the load, transmission line and the source generator should be well matched.
In case of any mismatch the incident energy is reflected back and start to accumulate in the transmission line as form of standing waves. The ratio of minimum and maximum points of standing wave is termed as the VSWR. Thus it describes how well an antenna is matched to the transmission line. VSWR is a function of the reflection coefficient ($S_{11}$ or return loss), which describes the power reflected from the antenna [3].

### 2.2.4 Bandwidth

The antenna bandwidth is another significant parameter in the design of antennas. It can be defined as the range of frequencies at with the antenna can efficiently radiate and receive information. Depending upon the bandwidth the antenna can be nominated as a wideband or narrowband antennas. Both types of antenna are known for their own applications. If an antenna is radiating at a center frequency of $f_c$ then the fractional bandwidth can be defined as in this Equation 2.2 and Figure 2.2:

$$Bandwidth = \left( \frac{f_2 - f_1}{f_c} \right) \times 100$$ \hspace{1cm} (2.2)

Where

- $F_1$ = lower frequency that coincide with the -10 dB return loss value.
- $F_2$ = upper frequency that coincide with the -10 dB return loss value.
- $F_c$ = center frequency.

![Figure 2.2: Bandwidth for Antenna](image)
2.2.5 Radiation pattern

The radiation pattern of an antenna can be defined as the directionality 3D radiated energy in space. The radiation pattern can be measured in near field or far field. In Euclidean plane the antenna pattern can be described in terms of azimuth and elevation pattern. An elevation pattern of an omnidirectional antenna while looking at antenna from the azimuth is presented in Figure 2.3(a) while the elevation pattern is presented in Figure 2.3(b). The elevation pattern and the azimuth patterns can be combined it produced a 3D pattern of the antenna. The 3D pattern of an antenna with omnidirectional pattern is presented in Figure 2.3(c). The common terms related to radiation patterns include the level of side lobes, back lobes and the main lobe magnitude. In case of omnidirectional patterns, the antenna radiates constantly in the horizontal plane and may differ in vertical plane. It is seen that this pattern is non-directional in the azimuth plane \([f(\phi), \theta=\pi/2]\) and directional in the elevation plane \([g(\theta), \phi = \text{constant}]\) [4].

![Figure 2.3: Radiation Pattern for Antenna](image)

2.2.6 Power gain

The power gain of an antenna is a ratio of the power input to the antenna to the power output from the antenna. This gain is most often referred to with the units of dBi, which is logarithmic gain relative to an isotropic antenna. An isotropic antenna has a perfect spherical radiation pattern and a linear gain of one. To calculate gain we use this Equation 2.3.
\[ G = \eta \times D \quad (2.3) \]

Where:
- \( G \) = gain
- \( \eta \) = efficiency
- \( D \) = directivity

### 2.2.7 Directivity

Directivity is the ability of an antenna to focus energy in a particular direction when transmitting, or to receive energy better from a particular direction when receiving. In a static situation, it is possible to use the antenna directivity to concentrate the radiation beam in the wanted direction. However, in a dynamic system where the transceiver is not fixed, the antenna should radiate equally in all directions, and this is known as an Omni-directional antenna [5].

### 2.2.8 Polarization

The orientation of electromagnetic waves coming from a source is termed as polarization. An electromagnetic signal comprises of both an electrical and magnetic field. The polarization of an electrical signal is determined by the direction of the electric field radiated out of antenna and the surface of the earth.

Polarization of antennas is of different types. The types are of linear, vertical and horizontal, circular and elliptical polarizations. The antenna radiates along only one axis in case of linear polarization. In case of circular polarization, the energy from the antenna is radiated along both the vertical and the horizontal axis. There is phase shift of quarter wave between the two radiated fields. Polarization is an important parameter since without considering the polarization of the host antenna the desired signal will be lost.
REFERENCES


