DEVELOPMENT OF A CIRCULAR COMPLEMENTARY SPLIT RING RESONATOR MICROSTRIP ANTENNA FOR HIGH ALTITUDE PLATFORM STATION

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By

MUHAMMAD EZANUDDIN BIN ABDUL AZIZ
(0830810285)

A thesis submitted
In fulfilment of the requirements for the degree of
Master of Science (Communication Engineering)

School of Computer and Communication Engineering
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LIST OF ABRREVIATIONS

2G	Second Generation
3D	Three dimensional
ABW	Absolute bandwidth
ACMPA	Aperture-coupled microstrip patch antenna
AR	Axial ratio
ASCII	American National Standard Code for Information Interchange
BER	Bit Error Rate
BFWA	Broadband Fixed Wireless Access
CCSRR	Circular complementary split ring resonator
CPW	Coplanar Waveguide
CSL	Coupled Slot Antenna
CST	Computer Simulation Technology
CSRR	Complementary split ring resonator
CW	Continuous Wave
DNG	Double negative
DUT	Device under test
ERP	Effective radiated power
FBW	Fractional Bandwidth
FCC	Federal Communication Commission
FEM	Finite Element Method
FS	Free space
FFT	Fast Fourier Transform
HAPS	High Altitude Platform Station
IMT	International Mobile Telecommunications
ISM	Industrial Scientific and Medical (frequency bands)
ITU	International Telecommunication Union
ITU-R	Radio Communication Sector
MAFIA	A multi-purpose ECAD system designed to solve all kinds of electromagnetic problems

MLFMM	Multi Level Fast Multipole Method
MOM	Method of Moments
PNA	Programmable Network analyzer
PSTN	Public Switch Telecommunications Network
MTM	Metamaterial
MW	Microwave Studio
RF	Radio frequency
RL	Return loss
SRR	Split ring resonator
VSWR	Voltage Wave Standing Ratio
VNA	Vector Network Analyzer
WLAN	Wireless local area network

LIST OF SYMBOLS

ε_o	Free-space permittivity
ε_{eff}	Effective dielectric constant
ε_r	Relative permittivity of the dielectric material
ε_m	Relative permittivity of the conducting material
ε_m	Relative permittivity of the laminating dielectric material
f	Frequency
λ	Wavelength
λ_o	Wavelength in free space
λ_d	Wavelength in the dielectric substrate
G	Gain of the antenna
Q	Quality factor of the antenna
J_s	Current density
E	Electric field
H	Magnetic field
k	Propagation constant
k_o	Propagation constant in the free-space
k_l	Propagation constant in the metal conductor
t_m	Thickness of the conducting material
t_l	Thickness of the laminating dielectric material
t_c	Thickness of the laminated conductor
μ_o	Permeability of air
μ_m	Permeability of the conducting material
μ_l	Permeability of the laminating dielectric material
σ	Conductivity
σ_m	Conductivity of the conducting material
σ_l	Conducting of the laminating dielectric material
δ	Skin depth
α	Attenuation constant of propagation constant
η_o	Wave impedance (376.7 ohms)

θ	Theta, Elevation angle
φ	Phi, Azimuth angle
π	3.14159
ω	Angular frequency in radian/second

PEMBANGUNAN ANTENA LINGKARAN BERBELAH BERGEMA YANG SALING MELENGKAPI UNTUK STESEN BERALTITUD TINGGI

ABSTRAK

Di dalam tesis ini, pengaruh lingkaran berbelah bergema yang saling melengkapi dan jurang udara didampingi oleh tampungan bulatan jalurmikro untuk kegunaan antenna komunikasi radio gelonbang mikro stesen beraltitud tinggi masa depan Malaysia dikaji. Direncanakan bagi pengoperasian jalur spektrum 5.85 GHz ke 7.075 GHz, ianya difabrikasi daripada papan gelombang mikro RT/D 5880 (ε_r = 2.2 dan berketebalan 1.82 mm). Struktur antena ini dibahagikan kepada tiga lapisan berasingan terdiri daripada kepingan bulat tembaga bertindak sebagai punca bumi (lapisan pertama), satu penggetar kecil utama, di mana isyarat dan tenaga dikumpulkan dan disimpan, memfokus dan memancar semula ke lapisan atasnya (lapsian kedua) dan akhir sekali aluran lingkaran berbelah bergema yang melengkapi (lapisan ketiga) disokong oleh busa berdielektrik rendah (ε_r = 1.2). Kesemua lapisan adalah dijarakkan dengan jurang udara, disimulasi dan dioptimumkan bentuknya dalam perisian komputer, Studio Gelombang Mikro, keluaran Computer Simulation Technology Suite (CST). Kunci-kunci utama struktur/dimensi yang dimanipulasi dan dianalisis keadaannya adalah, jarak jurang udara, kedudukan penggetar bulatan tembaga kecil bersama suapan koksial, bilangan dan kelebaran lingkaran berbelah bergema yang melengkapi kepada tampalan bulatan tembaga individu pada lapisan ketiga. Setelah itu, perolehan kesemua nilai hilang balikkan, nisbah kedudukan gelombang keupayaan elektrik, dapatan sebenar dan kejauhan medan elektrik dan magnetik sama ada di dalam 2-dimensi, 3-dimensi dan taburan berpaksi diperbandingkan dan dianalisis semula. Antena sebenar yang telah diujikaji menunjukkan bacaan garisan hilang balikkan yang dalam lebih daripada -10 dB bermula pada 5.75 GHz hingga ke 7.25 GHz berbanding antenna simulasi yang berjulat 5.0 GHz hingga 7.5 GHz, pada nisbah kedudukan gelombang keupayaan elektrik 2:1. Secara keseluruhan, antena, setelah dilakukan perbandingan antara simulasi dan difarbikasi berjaya menghasilkan dapatan dan capaian yang stabil 5 dBi sepanjang jalur spektrum yang disasarkan Keputusan yang diperolehi menunjukkan pencantuman lingkaran berbelah bergema yang melengkapi telah membantu menambah baik prestasi asas antena dari segi mendapatkan semula kapasiti jalurlebar yang dikehendaki. Bagi memperoleh keadaan resonan gandaan negatif, kaedah eksperimentasi simulasi bahan-meta dua posisi/suapan masukan diguna pakai dan struktur lingkaran berbelah bergema ini didapati mampu menghasilkan bacaan negatif pada komposisi keboleh telusan elektrik dan keboleh resapan magnetik. Bacaan resonan gandaan negatif ini juga menambah baik kelancaran arus aliran elektrik permukaan, meninggikan nilai dapatan dan menyama ratakan fasa sinar didalam julat spektrum yang diingini. Penyelesaian berasaskan pergerakan masa didalam perisian CST juga membantu mensimulasi penyatuan antena bersama pesawat kecil. Membariskan antena-antena di hujung sayap pesawat (disimulasikan pada jarak 23 meter berbanding jarak keseluruhan sayap iaitu 37.46 meter) secara aturan didapati meningkatkan lagi bacaan dapatan. Antena ini telah menghasilkan nilai maksimum satah elektrik dan satah magnetik bersama dan lintangan pada perbezaan kebesaran 3.5 dB and satah elektrik kuasa separuh kelebaran sinar sebanyak 20^0.

DEVELOPMENT OF A CIRCULAR COMPLEMENTARY SPLIT RING RESONATOR ANTENNA FOR HIGH ALTITUDE PLATFORM STATION

ABSTRACT

In this thesis, the influences of Circular Complementary Split Ring Resonators (CCSRR) and air gap within the circular microstrip patch antenna structure are investigated for the use of Malaysia's future High Altitude Platform Station(HAPS) wireless communication. The proposed antenna is designed to operate from 5.850 GHz to 7.075 GHz spectrum band using microwave laminate RT/D 5880 (ε_r = 2.2 and thickness of 1.82 mm). The antenna structure was organized into three separate layers consisting of circular copper sheet as the ground plane (layer number one), an undersized main radiator, where the electromagnetic signal and energy gathered and stored, focuses and passes through (layer number two) to resonate its above layer and the etched slotted split ring resonators on the dielectric laminate (layer number three) supported by low dielectric foams (ε_r = 1.2). All layers are separated by an air gap, simulated and optimized using the Computer Simulation Technology Suite (CST), Microwave Studio software. The distance of air gap, the positioning of coaxial feed together with a small circular copper patch, the number and the width of the split ring resonators corresponding to each individual circular patch are varied and analyzed as the key player studies. The results of the return losses, VSWR, realized gain and farfield characteristics either in 2D, 3D or polar plot views obtained are compared and analyzed. Measurement of the fabricated antenna showed deep line return loss below -10 dB beginning at 5.75 GHz to 7.25 GHz as compared to simulations which were 5.0 GHz to 7.5 GHz (VSWR 2:1). Overall, the antenna, once compared between its simulations and fabricated managed to produce a stable 5 dBi gain and directivity along the targeted spectrum band. The results show that inclusion of split ring resonators have enhanced and improved the antenna fundamental performance and in terms of sustaining the targeted bandwidth. The CCSRR structure also managed to produce real part of permittivity and permeability readings into negative values through a two port numerical simulation, part of a metamaterial simulation experiment, that is to investigate Double Negative (DNG) characteristics. DNG characteristics helps to improve surface current flow raised the gain and beam phase within the frequency spectrum (the more negative the values of ε and μ become, a slight increase to the gain can be observed). CST MW powerful transient solver was able to simulate the antenna integration with a miniaturized plane the stratospheric M55. Deploying two antenna units on the M55 aircraft wings (separated at 23 meter apart, the total wingspan = 37.46 meter) have created an array formation and further increased the signal gain. The antenna produced maximum E-plane and H-plane co and cross polarization difference in the magnitude of 3.5 dB and E-plane half power beam width (HPBW) of 20^0.