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Analysis of RF Harvesting Circuit Using Microstrip Patch Antenna Array at 1.8 GHz as Harvester

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Abstract: *As Per The Growing Number Of Mobile Towers And Simultaneously Increase In Demand To Power Wireless Devices, RF Energy Harvesting System From Mobile Towers Will Prove Beneficial For Alternate Energy Harvesting Source. A High Gain Patch Antenna Array Is Developed. Germanium Diode As A Two Stage Rectifier Is Also Designed. High Gain Antenna Array Is Designed And Fabricated To Capture Maximum Signal Emitted By Transmitter. The Antenna Is Fabricated On FR_4 Substrate Having Low Cost Which In Turn Makes The Antenna Array A Cost Effective Solution For RF Energy Harvesting. The Designed, Simulated And Fabricated Antenna Array Which Achieved A Higher Gain Of 9.29db Has Lead To Increase The Size Of Antenna .The Antenna Works In 1800 GSM Band For Which It Was Made To Operate. The Purpose Of Designing A Four Patch Antenna Array Which Provides Better Value Of Return Loss As -24.07db The Fabricated Antenna Is Now Future Connected To A Rectifying Circuit To Work As A Receiver For Capturing RF Signal In RF Harvesting Circuit .The Analysis Of This Harvester Proved That RF Energy Harvesting Is A Promising Alternate Energy Source.*

I. Introduction

With The Increased Deployment Of Wireless Devices, Provision To Provide Energy For These Large-Scale Devices In An Eco-Friendly Way Is An Emerging Issue. As It Is Known That, Both Static And Mobile Charging Strategies Have Been Developed For Power Replenishment. However, These Strategies Developed So Far Pose Certain Drawbacks Such As More Pollution And Energy Consumption. .This Leads To The Progress In Development Of Wireless Charging Techniques To Provide A Promising Alternative Way To Address The Energy Recharging Methods And Techniques.

Energy Harvester Takes Its Fuel From Ambient Sources Such As Wind, Solar, Vibration, Electro-Magnetic Waves. Electromagnetic Waves Or Radio Waves Are Available In Our Environment From Various Signals Which Are Transmitted From TV Towers, Mobile Phones Towers, Radio Towers And Wireless Routers. For Employing Ambient RF Energy As Source For Energy Harvesting, The Most Appropriate Bands To Be Explored Are GSM 900 (935-960 Mhz), GSM 1800 (1805.2-1879.8mhz), Wi-Fi (2.4ghz) As The Radio Waves Emitted From These Source Are Not Utilized To Their Maximum Capacity.

The Ambient Electromagnetic Radiation Emitted From Different Sources Such As Wi-Fi Transmitters, Cell-Phone Antennas, TV Broadcast Systems, Mobile Transmitting Antennas And Other Sources Could Be Converted Into Enough Electrical Energy Which Can Be Further Stored In Different Ways To Meet The Energy Requirement. The Underlying Idea Is To Harness Energy From Radio Waves Travelling Around In The Air As Ambient Source To Produce Electricity As The Output. Although Power Generated From Radio Waves Is Of Low Intensity As Energy Density Decreases Over Distance, Hence This Low Energy Generated Can Be Used To Power Devices Which Run On Low Power Such As LED, Microprocessors, And Wireless Sensors Nodes And So On.

Among The Various Technique Listed Above Radio Waves Is Actually A Long Range Energy Providing Method[1].

The Main Objective Of The RF Energy Harvesting System Is To Convert RF Power Into Usable Electrical Energy. The Major Components Of The Energy Harvesting System Are Receiving Antenna And DC To RF Converter. The Ambient RF Signal Is Captured By An Antenna Is An AC Current And This Incident RF Signal Is Convert Into Dc Power By The Voltage Multiplier. Whereas The Matching Network Which Is Composed Of Inductive And Capacitive Elements, Ensures The Maximum Power Delivery From Antenna To The Voltage Multiplier. [2]

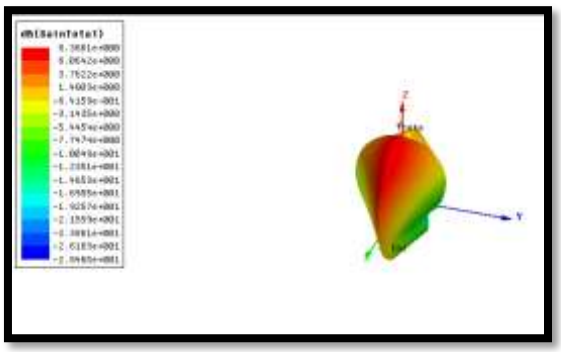
II. Antenna Design And Simulation

A High Gain Microstrip Four Patch Antenna Array Has Been Presented And Developed. It Has Successfully Achieved A Gain Of 9.2db At Resonant Frequency Of 1.78 Ghz; The Designed And Fabricated Antenna Will Work As Receiver For Capturing RF Signal In 1800mhz GSM Band. Two And Four Patch Antenna Has Been Fabricated And Can Be Used For Receiving RF Signal Emitted From Mobile Phone Towers Operating At GSM 1800 Mhz Band. Higher Gain Antenna Should Work Better As It Capable Of Capturing More RF Signal. Following Tableii.1 Shows The Specification For Antenna Designed.

Tableii.1 ANTENNA SPECIFICATIONS

Sr.No.	Antenna Dimensions		
	Parameters	Values	Units
1.	Central Or Operating Frequency (f_0)	1.8	Ghz
2.	Height Of Substrate (H)	1.6	Mm
3.	Dielectric Constant ϵ_r)	4.4	Constant
4	Length Of The Patch (L)	39	Mm
5.	Width Of The Patch (W)	52	Mm
6.	Length Of Microstrip Line Feed (L1)	21.8	Mm
7.	Width Of Microstrip Line Feed (W1)	2.5	Mm
8.	Length Of Slot (L2)	11	Mm
9.	Width Of Slot (W2)	7	Mm
10.	Distance Bewteen Two Adjectent Patches (H-Plane) (Y-Axis)	60.6	Mm
12	Distance Bewteen Two Adjectent Patches (E-Plane) (X-Axis)	66	Mm
13.	Width Of 70Ω Microstrip Line(W3)	1	Mm
14.	Length Of 70Ω Microstrip Line(L3)	50	Mm
15.	Width Of 50Ω Microstrip Line(W4)	3	Mm
16.	Length Of 50Ω Microstrip Line(L4)	15	Mm
17.	Length Of Microstrip Line Joinig 2X1 Array Patch (L5)	50	Mm
16.	Width Of Microstrip Line Joinig 2X1 Array Patch (W5)	3	Mm

The Antenna Proposed Antenna In This Paper Was A Four Patch Array Which Obtained Return Loss Of -25db And The Gain Obtained Is 9.2db At Resonant Frequency Of 1.78ghz But A Slight Shift In Central Frequency From 1.8ghz To 1.78ghz Has Been Observed. The Antenna Still Worked 1810-1880 Mhz (GSM) 1800 Band And Hence Is Suitable To Capture RF Signal For RF Energy Harvesting Circuit. The Proposed Structure Is Fabricated To Work As A Receiver For Capturing RF Signal In RF Harvesting Circuit.



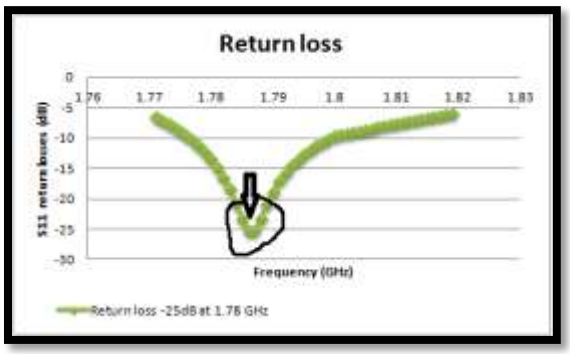


Fig.II.1. Gain Obtained For Four Patch Antenna **Fig.II.2** Return Loss Obtained For Four Patch Antenna

The Result Obtained For Gain And Return Losses Is Shown In Figii.1 &Fig II.2 .These Are The Results Obtained For Four Patch Antenna [3].

Rf To Dc Conversion Circuit Design

The RF-To-DC Conversion Efficiency Is Important For Increasing The Efficiency Of Energy Harvesting System. It Is Also Dependent On The Captured Signal Power Density At Receiving Antenna And Also On The Accuracy Of The Impedance Matching Between The Antenna And The Voltage Rectifier Circuit. In Designing A Rectifier Circuit With High RF-To-DC Conversion Efficiency Number Of Stage Of Diode Play A Vital Role.

The Proposed Circuit Of Rectifier Is A Two Stage Voltage Multiplier As Shown In Fig.III.1.

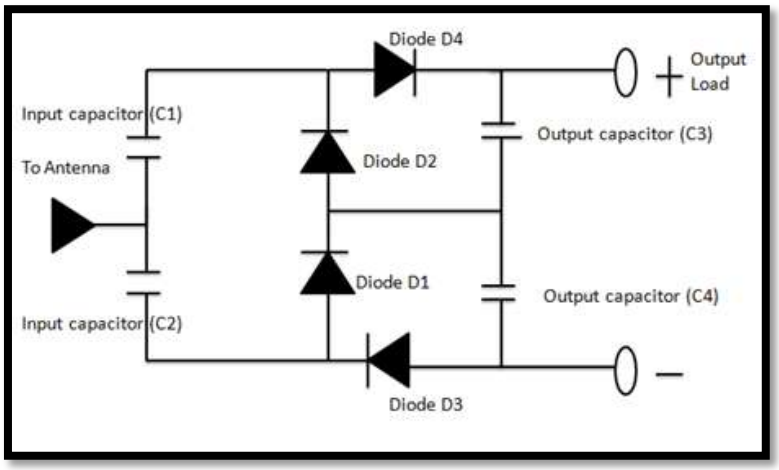


Fig III.1 Proposed Circuit For RF Rectifier Circuit

III. Choice Of Diode

Choosing A Diode Is One Of The Most Important Factors In Designing RF To DC Conversion Circuit. Since The Diode Is The Main Source Of Loss And Performance Of The Circuit Is Dependent On The Performance Of Diode. The Conversion Efficiency Of A Rectifier Is Mainly Determined By Three Parameters Of A Diode. For Rectification It Is Necessary To Select A Diode With Following Characteristics:

1. High Switching Speed In Order To Follow A High Frequency Input Signal
2. Low-Cut Off Voltage To Operate At A Low RF Input Power [4].

Germanium Diodes Have A Lower Forward Voltage Than Silicon Diodes And Hence They Are Able To Clip Signals At Lower Levels Than Silicon Diodes [5].

Diodes Which Meet Our Requirements Were Germanium Diode 1N34 [6].

The Proposed Rectifier Circuit Was Designed As Shown In Figiii.1.

Figiii.1. Rectifier Circuit For RF Harvester

IV. Result

Rectifier Circuit Is Tested In Laboratory At IIT-B By Connecting It To Signal Generator SMB 100A (9 Khz To 3.2ghz) Setting Input Frequency As 1.8 Ghz Which Is The Operational Frequency Of Antenna Array And Is Tested At Different Input RF Power Level As Shown In Fig.IV.1

Fig.IV.1 Experimental Setup For Testing Rectifier Circuit To Be Used In RF Harvester

Rectifier Response Is Measured At Different Input Power Level From 30dbm To -145dbm. Maximum Output Voltage Is Obtained At 30dbm As 1.134V.

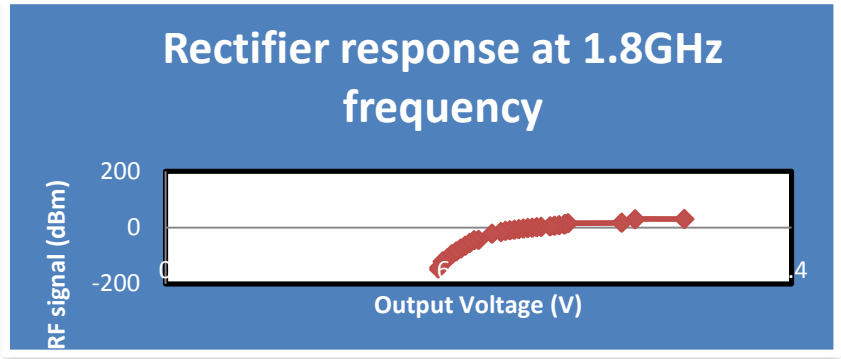


Fig IV.2 Response Of Rectifier At Various Input Voltage

V. Discussion

A Two Stage Rectifier Is A Designed Which Consists Of Germanium Diode To Be Connected To Antenna Array To Work As A RF Energy Harvester. The Rectifier Response Is Observed At Various Input Frequency So As To Verify Its Operation Range .The Rectifier Was Able To Obtain Output At Frequency Of Operation Of Antenna Array I.E 1.8 Ghz .This Shows That The Proposed Rectifier Circuit Can Be Connected To Antenna Array And Will Be Successful To Harvest RF Energy Form Mobile Towers.

VI. Conclusion

As Per The Growing Number Of Mobile Towers And Simultaneously Increase In Demand To Power Wireless Devices, RF Energy Harvesting System From Mobile Towers Will Prove Beneficial In:

1) Providing An Alternative Source Of Energy, As It Will Be Harvesting Ambient RF Signal.

2) Providing Awareness To People Living Close To Mobile Towers Regarding The Health Risks Of Mobile Phones Radiation.

Since We Have Already Designed And Tested Antenna Array For RF Energy Harvesting Circuit .This Paper Presented The Design Of Rectifier To Be Used For Along With Antenna Array To Work As A Harvester. The Proposed Rectifier Circuit Was Designed And Tested. The Result Obtained Shows That This Rectifier Circuit Can Be Successfully Used As Harvester Operating At 1.8ghz.

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