

**RECONFIGURABLE ACTIVE AND PASSIVE
PRINTED ANTENNAS**

RAJESH KUMAR SINGH



**BHARTI SCHOOL OF TELECOMMUNICATION
TECHNOLOGY AND MANAGEMENT
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RECONFIGURABLE ACTIVE AND PASSIVE PRINTED ANTENNAS

by

Rajesh Kumar Singh

Bharti School of Telecommunication Technology and Management

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This dissertation is dedicated to my family, teachers and my
friends

CERTIFICATE

This is to certify that the work reported in this thesis entitled “**RECONFIGURABLE ACTIVE AND PASSIVE PRINTED ANTENNAS**” being submitted by **Mr. Rajesh Kumar Singh** for the award of the degree of **Doctor of Philosophy** to the Indian Institute of Technology Delhi, New Delhi, India, is a record of original bonafide research work carried out by him under our guidance and supervision. The results contained in this thesis have not been submitted in part or full, to any other university or institute for the award of any degree or diploma.

We certify that he has pursued the prescribed course of research.

Prof. Ananjan Basu

Professor

Centre for Applied Research

in Electronics (CARE)

Indian Institute of Technology Delhi,

New Delhi – 110016, India.

Prof. Shibhan K. Koul

Professor

Centre for Applied Research

in Electronics (CARE)

Indian Institute of Technology Delhi,

New Delhi – 110016, India.

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ABSTRACT

This thesis work is focused on developing novel printed reconfigurable antennas and their applications in current and future wireless communication systems. Some novel reconfigurable passive and active antennas are demonstrated in this thesis. Reconfiguration is achieved by employing PIN diodes.

Single microstrip feed polarization reconfigurable antennas were developed first. A reconfigurable stub loaded microstrip patch antenna with polarization switching between different polarization states was presented. Two stubs were connected at two corners of the microstrip patch by using two PIN diodes. A reconfigurable V-shaped corner truncated microstrip patch antenna with switchable polarization was discussed. Circular polarization was achieved by truncating only one corner of the patch and switching in three different polarization states was achieved by using two PIN diodes. Both designs have good axial ratio (axial ratio < 3 dB) and impedance match ($S_{11} < -10$ dB) at operating frequencies. Three polarization states i.e., left-hand circular polarization, linear polarization, and right-hand circular polarization were achieved in all proposed designs. V-shaped corner truncated polarization switchable reconfigurable antenna was tested at high RF power and measured its performance.

A compound reconfigurable microstrip patch antenna with polarization agility in two switchable bands was developed next. The proposed antenna was capable of operating in three polarization states, i.e., left-hand circular polarization, linear polarization, and right-hand circular polarization in two switchable frequency bands. Additionally, the impedance bandwidth and axial ratio bandwidth were enhanced by using proximity coupled feed. Microstrip-fed reconfigurable patch antenna with polarization agility in two switchable bands was tested at high power, and limits on operating power levels studied. Next, a novel high gain polarization switchable rectangular slot antenna was designed and demonstrated. It can be switched among three different polarization states, i.e., left-hand circular polarization, linear polarization, and right-hand circular polarization.

A compact reconfigurable circular arc-shaped rectangular slot antenna was developed by using three PIN diodes. Further the impedance and axial ratio bandwidths were enhanced by replacing the circular arc-shaped rectangular slot with the circular slot. The measured overlapped impedance bandwidth for left-hand circular polarization and right-hand circular polarization was more than 1445 MHz (26.5%). The measured axial ratio bandwidths were more than 1412 MHz (25.9%).

An asymmetric coupled polarization switchable active integrated antenna was developed and compared with the symmetric coupled polarization switchable active integrated antenna. The transmitted power of an asymmetrical coupled active integrated antenna was 4.5 dB higher than that of symmetric coupled active integrated antenna under the same impedance matching condition. A new topology to reconfigure the radiation pattern in feedback-type oscillating active integrated antenna was proposed and demonstrated. Three states (main beam at $\theta = 0^{\circ}$, $+30^{\circ}$, and -30°) of the radiation pattern were achieved from beam steering oscillating active integrated antenna. An oscillating active integrated antenna having switchable pattern among sum or difference was developed. This active integrated antenna had a null depth of -12.45 dB from peak in the difference pattern. Further improvement in the null depth (-19.86 dB) was obtained from a modified active integrated antenna structure. The measured phase noise was better than -105 dBc/Hz at 1 MHz offset from carrier frequency in both patterns. The dc-to-RF efficiencies were better than 34.05%.

Slot antenna arrays with non-uniform amplitude excitations were developed to broaden the angular ranges of nulls. Two configurations of slot array were presented to broaden the angular range of null. Null broadening was achieved by varying the amplitude excitations of the slot elements. Broad nulls with null depth of ≤ -20 dB from peak were achieved in the angular range of 30° for the first configuration and 45° for the second configuration. Null switching was obtained from the second configuration and shifts the null from $\theta = \pm 90^{\circ}$ to $\theta = 0^{\circ}$ and 180° directions.

सार

यह थीसिस कार्य नव मुद्रित पुनर्नवीनीकरण एंटेना और उनके अनुप्रयोगों को वर्तमान और भविष्य के वायरलेस संचार प्रणालियों में विकसित करने पर केंद्रित है। इस थीसिस में कुछ नए निष्क्रिय और सक्रिय एंटेना प्रदर्शित किए गए हैं। पिन डायोड को नियोजित करके पुनर्नवीनीकरण हासिल किया गया है।

पहले एकल माइक्रोस्ट्रिप फीड ध्रुवीकरण पुनर्नवीनीकरण एंटेना विकसित किए गए थे। विभिन्न ध्रुवीकरण स्थिति के बीच ध्रुवीकरण स्विचिंग के साथ एक पुनर्नवीनीकरण स्टब लोड माइक्रोस्ट्रिप पैच एंटीना प्रस्तुत किया गया था। दो पिन डायोड का उपयोग करके माइक्रोस्ट्रिप पैच के दो कोनों पर दो स्टब्स जुड़े थे। स्विच करने योग्य ध्रुवीकरण के साथ एक पुनर्नवीनीकरण योग्य वी-आकार में कोने कटे हुए माइक्रोस्ट्रिप पैच एंटीना पर चर्चा की गई। पैच के केवल एक कोने को काटकर वृत्तीय ध्रुवीकरण प्राप्त किया गया था और दो पिन डायोड का उपयोग करके तीन अलग ध्रुवीकरण स्थिति में स्विचिंग हासिल की गई थी। दोनों डिज़ाइनों में ऑपरेटिंग आवृत्तियों पर अच्छा अक्षीय अनुपात (अक्षीय अनुपात <3 डीबी) और प्रतिबाधा मिलान (S11 <-10 डीबी) प्राप्त होता है। तीन ध्रुवीकरण स्थिति अर्थात्, बाएं हाथ के वृत्तीय ध्रुवीकरण, रेखिक ध्रुवीकरण, और दाएं हाथ के वृत्तीय ध्रुवीकरण सभी प्रस्तावित डिज़ाइनों में हासिल किए गए थे। वी-आकार में कोने कटे हुए ध्रुवीकरण स्विच करने योग्य पुनर्नवीनीकरण एंटीना उच्च आरएफ शक्ति पर परीक्षण किया गया था और इसके व्यवहार को मापा गया था।

दो स्विच करने योग्य बैंड में ध्रुवीकरण स्विचिंग के साथ एक यौगिक पुनर्नवीनीकरण माइक्रोस्ट्रिप पैच एंटीना विकसित किया गया था। प्रस्तावित एंटीना तीन ध्रुवीकरण स्थिति, यानी बाएं हाथ के वृत्तीय ध्रुवीकरण, रेखिक ध्रुवीकरण, दाएं हाथ के वृत्तीय ध्रुवीकरण और स्विच करने योग्य दो आवृत्ति बैंड में काम करने में सक्षम था। इसके अतिरिक्त, प्रॉक्सिमिटी युग्मित फीड का उपयोग करके प्रतिबाधा बैंडविड्थ और अक्षीय अनुपात बैंडविड्थ बढ़ाया गया था। दो स्विच करने योग्य बैंडों में ध्रुवीकरण स्विचिंग के साथ माइक्रोस्ट्रिप-फेड पुनर्नवीनीकरण पैच एंटीना का परीक्षण उच्च शक्ति पर किया गया था, और ऑपरेटिंग पावर स्तर की सीमा पर अध्ययन किए गए। एक नव उच्च लाभ ध्रुवीकरण स्विच करने योग्य आयताकार स्लॉट एंटीना डिज़ाइन प्रदर्शित किया गया था। इसे तीन अलग-अलग ध्रुवीकरण स्थिति, यानी बाएं हाथ के वृत्तीय ध्रुवीकरण, रेखिक ध्रुवीकरण, और दाहिने हाथ के वृत्तीय

ध्रुवीकरण के बीच स्विच किया जा सकता है। एक कॉम्पैक्ट पुनर्नवीनीकरण गोल चाप आकार का स्लॉट एंटीना तीन पिन डायोड का उपयोग करके विकसित किया गया था। आगे प्रतिबाधा मिलान बैंडविड्थ और अक्षीय अनुपात बैंडविड्थ गोलाकार चाप के आकार के आयताकार स्लॉट को गोलाकार स्लॉट के साथ बदलकर बढ़ाया गया था। बाएं हाथ के और दाएं हाथ के वृत्तीय ध्रुवीकरण के लिए मापा हुआ ओवरलैप्ड प्रतिबाधा बैंडविड्थ 1445 मेगाहर्ट्ज (26.5%) से अधिक था। अक्षीय अनुपात बैंडविड्थ 1412 मेगाहर्ट्ज (25.9%) से अधिक थे।

एक असममित युग्मित ध्रुवीकरण स्विच करने योग्य सक्रिय संघटित एंटीना विकसित किया गया था और सममित युग्मित ध्रुवीकरण स्विच करने योग्य सक्रिय संघटित एंटीना के साथ तुलना की गई थी। एक असममित युग्मित सक्रिय एकीकृत एंटीना की प्रेषित शक्ति समान प्रतिबाधा मिलान स्थिति के तहत सममित युग्मित सक्रिय एकीकृत एंटीना की तुलना में 4.5 डीबी अधिक थी। फीडबैक-प्रकार में रेडिएशन पैटर्न को फिर से कॉन्फ़िगर करने के लिए एक नई टोपोलॉजी को प्रस्तावित और प्रदर्शित किया गया था। सक्रिय संघटित एंटीना के साथ बीम स्टीयरिंग से रेडिएशन पैटर्न की तीन स्थिति ($\theta = 0^\circ$, $+30^\circ$, और -30° पर मुख्य बीम) प्राप्त की गई थी। योग या अंतर के बीच स्विच करने योग्य रेडिएशन पैटर्न वाला एक सक्रिय संघटित एंटीना विकसित किया गया था। इस सक्रिय संघटित एंटीना के अंतर पैटर्न में 12.45 डीबी की गहराई थी। एक संशोधित सक्रिय संघटित एंटीना संरचना की गहराई (-17.37 डीबी) में और सुधार प्राप्त किया गया था। दोनों पैटर्न में ऑपरेटिंग आवृत्ति से 1 मेगाहर्ट्ज ऑफसेट पर मापा हुआ फेज नॉइज़ -105 डीबीसी / हर्ट्ज नीचे था। डीसी-टू-आरएफ क्षमता 28% से बेहतर थी।

नॉन-यूनिफार्म एम्पलीटूड उत्तेजना वाले स्लॉट एंटीना ऐरे को नल की एंगुलर रेंज विस्तृत करने के लिए विकसित किया गया था। नल की एंगुलर रेंज को विस्तृत करने के लिए स्लॉट ऐरे की दो कॉन्फ़िगरेशन प्रस्तुत की गई थीं। स्लॉट एलिमेंट्स के एम्पलीटूड को बदलकर विस्तृत एंगुलर रेंज को हासिल किया गया था। शून्य से 20 डीबी की गहराई के साथ ब्रॉड नल को पहले कॉन्फ़िगरेशन के लिए 30° की एंगुलर रेंज और दूसरी कॉन्फ़िगरेशन के लिए 45° की एंगुलर रेंज में हासिल किया गया था। दूसरी कॉन्फ़िगरेशन में नल स्विचिंग प्राप्त की गई थी और शून्य को $\pm 90^\circ$ से 0° और 180° दिशाओं में बदल दिया गया था।

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LIST OF ABBREVIATIONS

AA	Active Antenna
ADS	Advanced Design System
AIA	Active Integrated Antenna
ARBW	Axial Ratio Bandwidth
BLC	Branch Line Coupler
BSF	Band Stop Filter
CP	Circular Polarization
CST	Computer Simulation Technology
CW	Continuous Wave
dB	Decibel
dBm	Decibel reference to 1 mW
dBc	Decibel reference to Carrier
DC	Direct Current
EIRP	Effective Isotropic Radiated Power
GPS	Global Positioning System
HJFET	Hetero-Junction Field Effect Transistor
Hz	Hertz
IMBW	Impedance Bandwidth
IEEE	Institute of Electrical and Electronics Engineering
LHCP	Left Hand Circular polarization
LP	Linear Polarization

MIC	Microwave Integrated Circuit
PIN	P type – Intrinsic – N type
RHCP	Right Hand Circular polarization
RF	Radio Frequency
RFID	Radio Frequency Identification
SMA	Sub Miniature A type
VNA	Vector Network Analyzer
WLAN	Wireless Local Area Network
WPD	Wilkinson Power Divider