NASA/TM—2002-211353

Polarization Reconfigurable Patch Antenna Using Microelectromechanical Systems (MEMS) Actuators

Rainee N. Simons
Glenn Research Center, Cleveland, Ohio

Donghoon Chun and Linda P.B. Katehi
University of Michigan, Ann Arbor, Michigan

April 2002

The NASA STI Program Office . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the Lead Center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized data bases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at ***http://www.sti.nasa.gov***

- E-mail your question via the Internet to help@sti.nasa.gov

- Fax your question to the NASA Access Help Desk at 301–621–0134

- Telephone the NASA Access Help Desk at 301–621–0390

- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076

NASA/TM—2002-211353

Polarization Reconfigurable Patch Antenna Using Microelectromechanical Systems (MEMS) Actuators

Rainee N. Simons
Glenn Research Center, Cleveland, Ohio

Donghoon Chun and Linda P.B. Katehi
University of Michigan, Ann Arbor, Michigan

Prepared for the
2002 Antennas and Propagation Society International Symposium
and URSI National Radio Science Meeting
sponsored by the Institute of Electrical and Electronics Engineers
San Antonio, Texas, June 16–21, 2002

National Aeronautics and
Space Administration

Glenn Research Center

April 2002

This report contains preliminary findings, subject to revision as analysis proceeds.

Available from

NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22100

Available electronically at http://gltrs.grc.nasa.gov/GLTRS

POLARIZATION RECONFIGURABLE PATCH ANTENNA USING MICROELECTROMECHANICAL SYSTEMS (MEMS) ACTUATORS

Rainee N. Simons
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio 44135

Donghoon Chun and Linda P.B. Katehi
University of Michigan
Ann Arbor, Michigan 48109-2122

I. INTRODUCTION

The capability to dynamically reconfigure the radiation patterns of planar antennas through geometric reconfiguration is essential for undertaking diverse missions [1]. This is made possible through the use of microelectromechanical systems (MEMS) based switching and actuating devices or circuits. The MEMS devices offer the following advantages over semiconductor devices: (1) significant reduction in insertion loss, (2) they consume an insignificant amount of power during operation, and (3) higher linearity hence lower signal distortion. Typical examples of MEMS based antennas are reported in [2] to [8].

In this paper, we present the first ever polarization reconfigurable patch antenna via use of integrated MEMS actuator. The key feature of this approach is: (1) the ability of a nearly square patch to dynamically reconfigure the polarization from circular to linear, thus providing polarization diversity and (2) the MEMS actuator is housed within the patch and does not require additional space. This feature is particularly important in the construction of a N by N planar array antenna with small inter-element spacing.

II. MEMS ACTUATOR INTEGRATION AND OPERATION

A nearly square patch antenna with integrated MEMS actuator is shown in Fig. 1. Briefly the actuator consists of a moveable metal overpass suspended over a metal stub. The overpass is supported at both ends by metalized vias which are electrically connected to the nearly square patch antenna. The metal overpass is actuated by an electrostatic force of attraction set up by a voltage applied between the overpass and the metal stub. A dielectric film deposited over the metal stub prevents stiction when the surfaces come in contact. The design of the MEMS actuator is presented in [2]. The MEMS actuator as viewed from the top is shown in the photomicrograph in Fig. 1.

The nearly square patch antenna with notches illustrated in Fig.1, is designed to support two degenerate orthogonal modes when excited at a corner [9], [10]. When the MEMS actuator is in the OFF-state the perturbation of the modes is negligible and hence the patch radiates a circularly polarized (CP) wave. When an electrostatic force resulting from the application of a bias pulls down the overpass, the MEMS actuator is in the ON-state. This action perturbs the phase relation between the two modes causing the patch to radiate dual linearly polarized (LP) waves.

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

The measured return loss for the OFF-state of the actuator is shown in Fig. 2. The patch is well matched to the 50Ω feed line and resonates at a frequency of 26.7 GHz. In the OFF-state the patch radiates a circularly polarized wave. To measure the radiation patterns, the RF probe station is modified to accommodate an open-ended rectangular waveguide (WR-42) as the rotating linearly polarized receiving antenna. The open-ended waveguide is attached to a Plexiglas™ fixture and is driven along an arc by a stepper motor. Thus the spinning open-ended waveguide can measure the relative field intensity of the patch as a function of the angle from boresight. The experimental setup is illustrated in Fig. 3. The measured radiation patterns along the two orthogonal planes are shown in Fig. 4. The measured axial ratio at boresight is about 2.0 dB.

The measured return loss for the ON-state of the actuator is also shown in Fig. 2. In the ON-state also the patch is well matched to the 50Ω feed line and resonates at a frequency of 26.625 GHz. The change in the resonance frequency for the two states is considered to be small. In the ON-state, the patch radiates dual linearly polarized waves. The measured E- and H-plane radiation patterns for the vertical polarization are shown in Fig. 5. Similar radiation patterns are observed for the horizontal polarization.

IV. CONCLUSIONS

A novel polarization reconfigurable patch antenna with integrated MEMS actuators is presented for the first time. This patch can be dynamically reconfigured to radiate either a circularly polarized or dual linearly polarized radiation patterns.

REFERENCES

[1] J.K. Smith, "Reconfigurable Aperture Program (RECAP)—MEMS Revolutionary Impact on RF Systems," Notes of the Workshop "RF MEMS for Antenna Applications," 2000 IEEE Ant. and Prop. Inter. Symp., Salt Lake City, Utah, July 16, 2000.

[2] R.N. Simons, D. Chun, and L.P.B. Katehi, "Microelectromechanical Systems (MEMS) Actuators for Antenna Reconfigurability," 2001 IEEE MTT-S Inter. Microwave Symp. Dig., Vol. 1, pp. 215–218, Phoenix, Arizona, May 20–25, 2001.

[3] R.N. Simons, D. Chun, and L.P.B. Katehi, "Reconfigurable Array Antenna Using Microelectromechanical Systems (MEMS) Actuators," 2001 IEEE Ant. and Prop. Inter. Symp. Dig., Vol. 3, pp. 674–677, Boston, Massachusetts, July 8–13, 2001.

[4] J.H. Schaffner, D.F. Sievenpiper, R.Y. Loo, J.J. Lee, and S.W. Livingston, "A Wideband Beam Switching Antenna Using RF MEMS Switches," 2001 IEEE Ant. and Prop. Inter. Symp. Dig., Vol. 3, pp. 658–661, Boston, Massachusetts, July 8–13, 2001.

[5] C.-W. Baek, S. Song, C. Cheon, Y.-K. Kim, and Y. Kwon, "2-D Mechanical Beam Steering Antenna Fabricated Using MEMS Technology," 2001 IEEE MTT-S Inter. Microwave Symp. Dig., Vol. 1, pp. 211–214, Phoenix, Arizona, May 20–25, 2001.

[6] C. Bozler, et al., "MEMS Microswitch Arrays for Reconfigurable Distributed Microwave Components," 2000 IEEE Ant. and Prop. Inter. Symp., Dig., Vol. 2, pp. 587–591, Salt Lake City, Utah, July 16–21, 2000.

[7] J.-C. Chiao, Y. Fu, I.M. Chio, M. DeLisio, and L.-Y. Lin, "MEMS Reconfigurable Vee Antenna," 1999 IEEE MTT-S Inter. Microwave Symp. Dig., Vol. 4, pp. 1515–1518, Anaheim, California, June 13–19, 1999.

[8] D. Chauvel, N. Haese, P.-A. Rolland, D. Collard, and H. Fujita, "A Micro-Machined Microwave Antenna Integrated with its Electrostatic Spatial Scanning," Proc. IEEE Tenth Annual Inter. Workshop on Micro Electro Mechanical Systems (MEMS 97), pp. 84–89, Nagoya, Japan, Jan. 26–30, 1997.
[9] C.A. Balanis, Antenna Theory, Analysis and Design, 2nd ed., New York: John Wiley and Sons, 1997, Section 14.7.
[10] R. Garg, P. Bhartia, I. Bahl, and A. Ittipiboon, Microstrip Antenna Design Handbook, Norwood, Massachusetts: Artech House, 2001, p. 497.

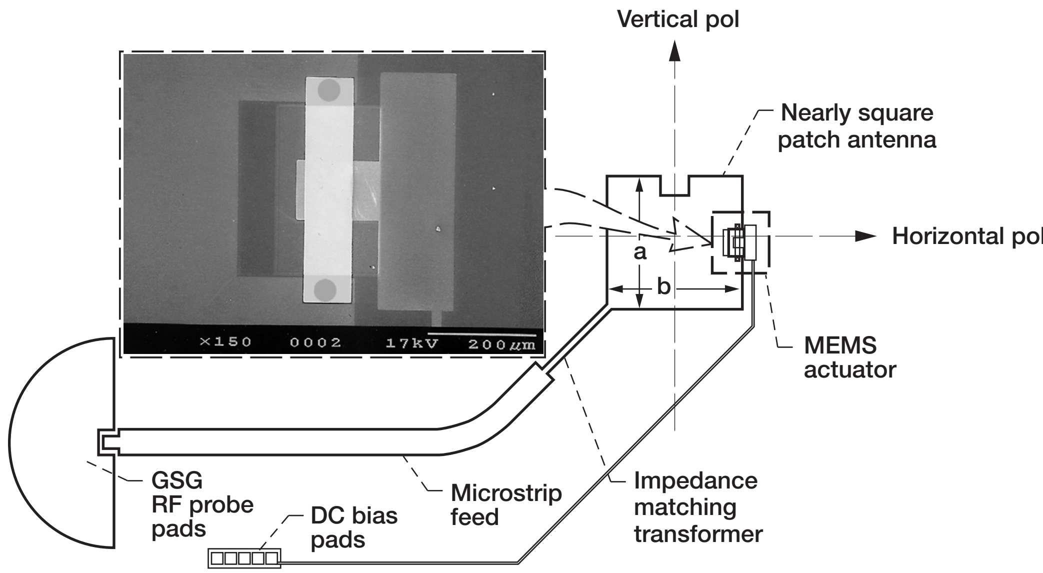

Figure 1.—Polarization reconfigurable patch antenna element with integrated MEMS actuator, a = 1500 μm and b = 1492 μm. Inset shows photomicrograph of the MEMS actuator.

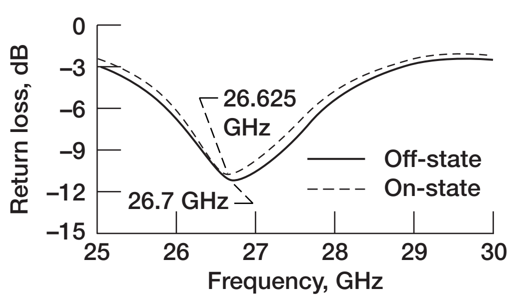

Figure 2.—Measured return loss.

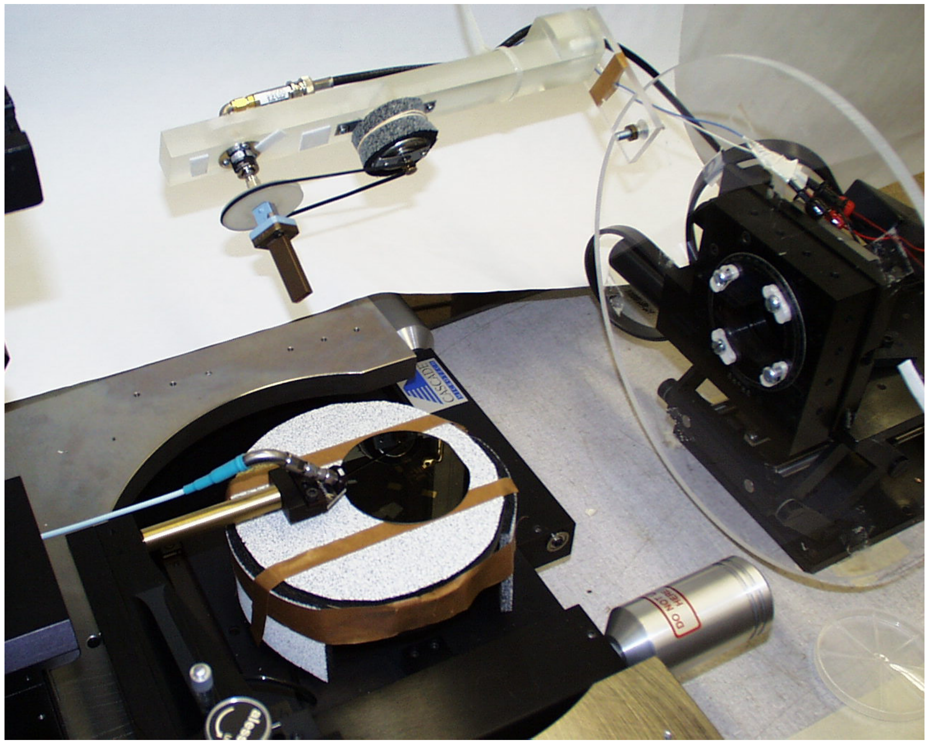

Figure 3.—Computer controlled on-wafer CP radiation pattern measurement set-up using a rotating linearly polarized pick-up antenna for MEMS actuator based patch antennas (surrounding microwave absorber panels have been removed).

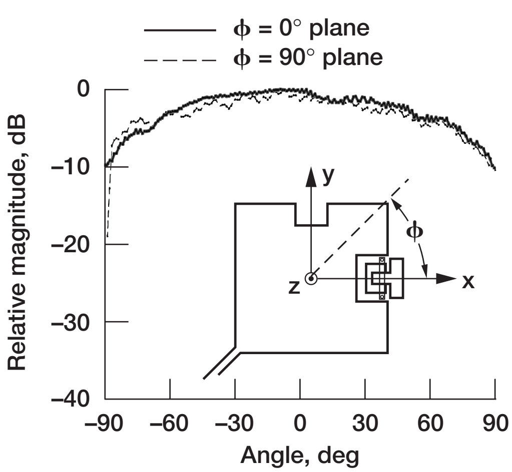

Figure 4.—Measured circularly polarized radiation patterns.

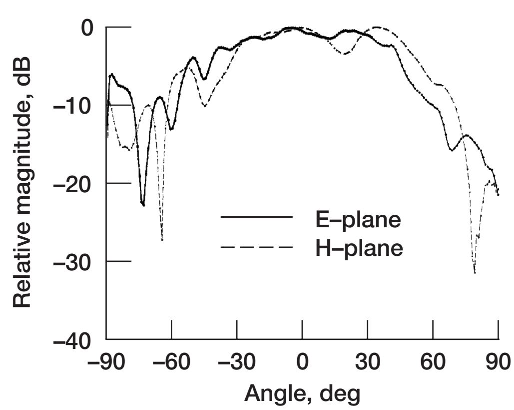

Figure 5.—Measured linearly polarized radiation patterns for vertical polarization.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)

2. REPORT DATE
April 2002

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
Polarization Reconfigurable Patch Antenna Using Microelectromechanical Systems (MEMS) Actuators

5. FUNDING NUMBERS
WU–755–08–0B–00

6. AUTHOR(S)
Rainee N. Simons, Donghoon Chun, and Linda P.B. Katehi

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
John H. Glenn Research Center at Lewis Field
Cleveland, Ohio 44135–3191

8. PERFORMING ORGANIZATION REPORT NUMBER
E–13171–1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546–0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA TM—2002-211353

11. SUPPLEMENTARY NOTES
Prepared for the 2002 Antennas and Propagation Society International Symposium and URSI National Radio Science Meeting sponsored by the Institute of Electrical and Electronics Engineers, San Antonio, Texas, June 16–21, 2002. Rainee N. Simons, NASA Glenn Research Center; Donghoon Chun and Linda P.B. Katehi, University of Michigan, Radiation Laboratory, EECS Department, Ann Arbor, Michigan 48109–2122. Responsible person, Rainee N. Simons, organization code 5620, 216–433–3462.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited
Subject Category: 33   Distribution: Nonstandard

Available electronically at http://gltrs.grc.nasa.gov/GLTRS
This publication is available from the NASA Center for AeroSpace Information, 301–621–0390.

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***
The paper demonstrates a nearly square patch antenna integrated with a novel microelectromechanical systems (MEMS) actuator for reconfiguring the polarization. Experimental results demonstrate that at a fixed frequency, the polarization can be reconfigured from circular to linear.

14. SUBJECT TERMS
Microelectromechanical systems; MEMS; Circular polarization; Dual linear polarization; Patch antenna; Microstrip line

15. NUMBER OF PAGES
10

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	