Suspended Patch Antenna Array With Electromagnetically Coupled Inverted Microstrip Feed

Raine N. Simons
Dynacs Engineering Company, Inc., Brook Park, Ohio

May 2000
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 databases, 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
Suspended Patch Antenna Array With Electromagnetically Coupled Inverted Microstrip Feed

Rainee N. Simons
Dynacs Engineering Company, Inc., Brook Park, Ohio

Prepared for the
Sixth Ka Band Utilization Conference
sponsored by the IIC—Istituto Internazionale delle Comunicazioni
Cleveland, Ohio, May 31–June 2, 2000

Prepared under Contract NAS3-98008

National Aeronautics and Space Administration
Glenn Research Center

May 2000
Acknowledgement

This work was performed under the task High Performance Printed Antennas and funded by the Cross Enterprise Technology Development Program (CETDP) in code SM.

This report is a preprint of a paper intended for presentation at a conference. Because of changes that may be made before formal publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.

Available from

NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076
Price Code: A03

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22100
Price Code: A03
SUSPENDED PATCH ANTENNA ARRAY WITH ELECTROMAGNETICALLY COUPLED INVERTED MICROSTRIP FEED

Raineen. Simons  
Dynacs Engineering Company, Inc.  
2001 Aerospace Parkway  
Brook Park, Ohio 44142  
Tel: (216) 433–3462  
Fax: (216) 433–8705  
E-mail: Raineen.Simons@grc.nasa.gov

Abstract
The paper demonstrates a four-element suspended patch antenna array, with a parasitic patch layer and an electromagnetically coupled inverted microstrip feed, for linear polarization at K-Band frequencies. This antenna has the following advantages over conventional microstrip antennas: First, the inverted microstrip has lower attenuation than conventional microstrip; hence, conductor loss associated with the antenna corporate feed is lower resulting in higher gain and efficiency. Second, conventional proximity coupled patch antennas require a substrate for the feed and a superstrate for the patch. However, the inverted microstrip fed patch antenna makes use of a single substrate, and hence, is lightweight and low cost. Third, electromagnetic coupling results in wider bandwidth. Details regarding the design and fabrication will be presented as well as measured results including return loss, radiation patterns and cross-polarization levels.

I. INTRODUCTION
Future space borne microwave/millimeter-wave systems for direct data distribution from a low Earth orbiting satellite will require antennas which have high gain, high efficiency, wide bandwidth, low profile, light weight and low cost. At millimeter-wave frequencies conventional microstrip lines suffer from high conductor loss [1], [2]. The high conductor loss impacts the gain and the efficiency of an array antenna with corporate feed. The conductor loss can be reduced by constructing the feed network using low loss transmission media such as, inverted microstrip [1], [2], suspended microstrip [3] and suspended substrate stripline (SSS) [4]. In the past, a suspended patch antenna excited by an electromagnetically coupled inverted microstrip feed at S-Band frequencies has been demonstrated in [5]. Recently, a suspended rectangular/circular patch antennas with electromagnetically coupled inverted microstrip feed for dual polarization/frequency and circular polarization have been demonstrated at K-Band frequencies in [6] and [7], respectively.
In addition, a cavity backed circular aperture antenna with suspended substrate stripline (SSS) feed has been demonstrated at V-Band frequencies [8], [9].

In this paper, a four-element suspended patch antenna array with a parasitic patch layer on top and electromagnetically coupled to an inverted microstrip feed, for linear polarization is demonstrated at K-Band frequencies. This antenna has the following advantages over conventional microstrip antennas: First, the inverted microstrip has lower attenuation than conventional microstrip; hence, conductor loss associated with the antenna corporate feed is lower resulting in higher gain and efficiency. Second, the inverted microstrip is easier to fabricate, because the strip width is wider for a given characteristic impedance \(Z_0\) [10]. Third, conventional proximity coupled patch antennas require a substrate for the feed and a superstrate for the patch. However, the inverted microstrip fed patch antenna makes use of a single substrate, and hence, is lightweight and low cost. Fourth, electromagnetic coupling results in wider bandwidth. Details regarding the design and fabrication will be presented as well as measured results, which include return loss, radiation patterns, and cross-polarization levels.

II. ANTENNA CONSTRUCTION

An inverted microstrip line consists of a dielectric substrate (RT/Duroid 5880®, \(\varepsilon_r = 2.22\)) of thickness \(h_1\) (0.01 inch) separated from a ground plane by an air gap of height \(g_1\) (0.01 inch) as shown in Fig. 1. The strip conductor of width \(W_1\) (\(\approx 0.045\) inch for \(Z_0 = 50\ \Omega\)) is situated on the lower surface of the substrate facing the ground plane. A patch antenna is printed on the opposite side of the substrate and electromagnetically coupled to the inverted microstrip feed. A superstrate, of thickness \(h_2\) and dielectric constant \(\varepsilon_r = 2.22\) equal to 0.01 inch and 2.22 respectively, and with a parasitic patch on the top surface, is placed at a distance \(g_2\) equal to 0.125 inch above the substrate. A schematic of a single-element antenna with a parasitic patch on top, and with an electromagnetically coupled inverted microstrip feed, is shown in Fig. 2. The length \(L\) (0.18 inch) and width \(W\) (0.31 inch) of both the active and the parasitic patches are identical in the initial experiments. The overlap between the active patch and the feed line is indicated as \(S\). Based on the dimensions of this single-element antenna, a four-element array with inverted microstrip feed network is designed. The feed network is designed according to [11] and has the advantage of requiring fewer and shorter microstrip lines, thereby further reducing the feed loss. The T-junctions in the feed network
are designed according [12]. The center-to-center inter-element spacing is 0.3886 inch along both planes. Figs 3(a) and (b) show the mask of the feed network and the patch array, respectively.

III. EXPERIMENTAL RESULTS

The measured return loss of the four-element array is shown in Fig. 4. The measurements show that the array is very well matched to the 50 Ω feed lines and the -10.0 dB return loss bandwidth is about 5.4 percent for the initial experiments at K-Band frequencies. The array radiates with a linear polarization perpendicular to the feed. The measured E- and H-plane radiation patterns and the cross-polarization level for the array are shown in Fig. 5. The measured gain of the array as compared to a standard gain horn antenna is estimated to be about 10.0 dB.

IV. CONCLUSIONS

The paper demonstrates a four-element suspended patch antenna array, with a parasitic patch layer and an electromagnetically coupled inverted microstrip feed, for linear polarization at K-Band frequencies. The design, fabrication, and experimental results which include, return loss, E- and H-plane radiation patterns, and cross-polarization level are presented.

REFERENCES


---

Figure 1.—Cross-section showing a suspended patch antenna with a parasitic patch excited by an inverted microstrip line feed.

Figure 2.—Schematic of a patch antenna with a parasitic patch electromagnetically coupled to an inverted microstrip line feed for linear polarization.
Figure 3.—Mast layout of four element K-Band suspended patch antenna array. (a) Feed network (b) patch array.

Figure 4.—Measured return loss of the four element array.

Figure 5.—Co-pol and cross-pol radiation patterns at 22.5 GHz.
The paper demonstrates a four-element suspended patch antenna array, with a parasitic patch layer and an electromagnetically coupled inverted microstrip feed, for linear polarization at K-Band frequencies. This antenna has the following advantages over conventional microstrip antennas: First, the inverted microstrip has lower attenuation than conventional microstrip; hence, conductor loss associated with the antenna corporate feed is lower resulting in higher gain and efficiency. Second, conventional proximity coupled patch antennas require a substrate for the feed and a superstrate for the patch. However, the inverted microstrip fed patch antenna makes use of a single substrate, and hence, is lightweight and low cost. Third, electromagnetic coupling results in wider bandwidth. Details regarding the design and fabrication will be presented as well as measured results including return loss, radiation patterns and cross-polarization levels.