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Suspended Patch Antenna Array With Electromagnetically Coupled Inverted Microstrip Feed

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SUSPENDED PATCH ANTENNA ARRAY WITH ELECTROMAGNETICALLY COUPLED INVERTED MICROSTRIP FEED

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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®, $\varepsilon_{r1} = 2.22$) 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_i ($\approx$ 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 ε_{r2} 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) shows 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

[1] T. Itoh, "Overview of Quasi-Planar Transmission Lines," IEEE Trans. Microwave Theory Tech., vol. 37, no. 2, pp. 275–280, Feb. 1989.

[2] B.E. Spielman, "Dissipation Loss Effects in Isolated and Coupled Transmission Lines," IEEE Trans. Microwave Theory Tech., vol. MTT-25, no. 8, pp. 648–656, Aug. 1977.

[3] J.M. Baracco and A. Carlstrom, "X-Band Microstrip Array Antenna in Suspended Technology," 1997 IEEE Antennas and Propagation Society Inter. Symp. Dig., vol. 2, pp. 1256–1259, 1997.

[4] E. Rammos, "A Low Tolerance Dual Slot Radiator for Space and Ground Applications," 1991 IEEE Antennas and Propagation Society Inter. Symp. Dig., vol. 3, pp. 1599–1602, 1991.

[5] Q. Zhang, Y. Fukuoka, and T. Itoh, "Analysis of a Suspended Patch Antenna Excited by an Electromagnetically Coupled Inverted Microstrip Feed," IEEE Trans. Antennas and Propagation, vol. AP-33, no. 8, pp. 895–899, Aug. 1985.

[6] R.N. Simons, "Suspended Rectangular/Circular Patch Antennas with Electromagnetically Coupled Inverted Microstrip Feed for Dual Polarization/ Frequency," accepted for presentation at the 2000 IEEE International Symposium on Antennas and Propagation, July 16–21, 2000, Salt Lake City, Utah.

[7] R.N. Simons, "Suspended Patch Antennas with Electromagnetically Coupled Inverted Microstrip Feed for Circular Polarization," accepted for presentation at the 2000 IEEE International Symposium on Antennas and Propagation, July 16–21, 2000, Salt Lake City, Utah.

[8] R.N. Simons, "A Millimeter-Wave Cavity-Backed Suspended Substrate Stripline Antenna," 1999 IEEE Antennas and Propagation Society Inter. Symp. Dig., vol. 3, pp. 2110–2113, 1999.

[9] D. Chun, R.N. Simons, and L.P.B. Katehi, "Modeling and Characterization of Cavity Backed Circular Aperture Antenna with Suspended Stripline Probe Feed," accepted for presentation at the 2000 IEEE International Symposium on Antennas and Propagation, July 16–21, 2000, Salt Lake City, Utah.

[10] J. Rivera and T. Itoh, "Analysis of an Electromagnetically Coupled Patch Antenna," 1983 IEEE Antennas and Propagation Society Inter. Symp. Dig., vol. 1, pp. 170–173, 1983.

[11] M.L. Oberhart, Y.T. Lo and R.Q. Lee, "New Simple Feed Network for an Array Module of Four Microstrip Elements," Electronics Letters, vol.23, no. 9, pp. 436–437, April 1987.

[12] B.C. Wadell, Transmission Line Design Handbook, Norwood, Massachusetts: Artech House Inc., 1991, p. 315.

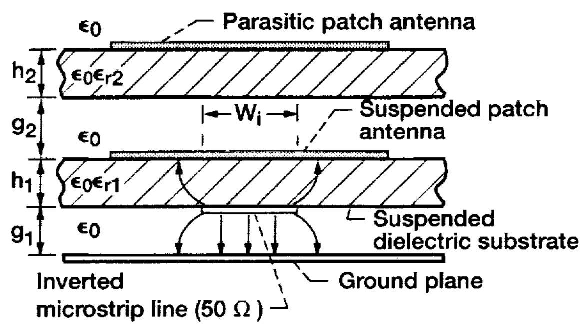

Figure 1.—Cross-section showing a suspended patch antenna with a parasitic patch excited by an inverted microstrip line feed.

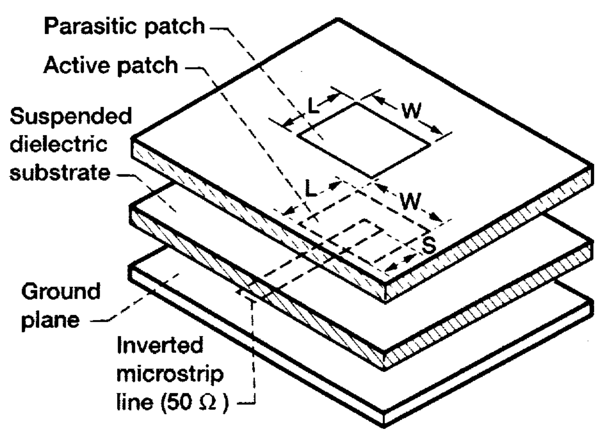

Figure 2.—Schematic of a patch antenna with a parasitic patch electromagnetically coupled to an inverted microstrip line feed for linear polarization.

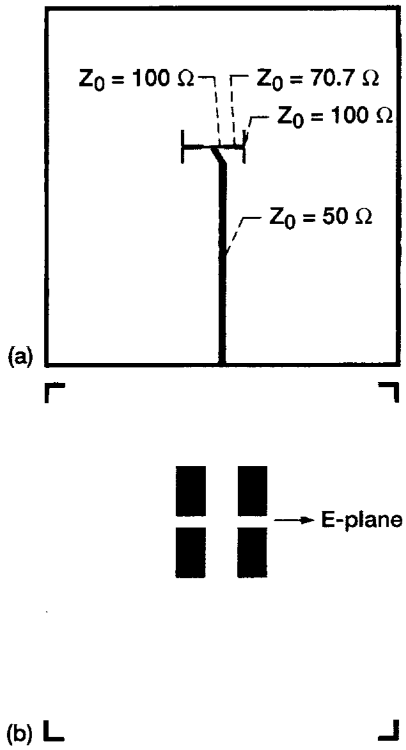

Figure 3.—Mast layout of four element K-Band suspended patch antenna array. (a) Feed network (b) patch array.

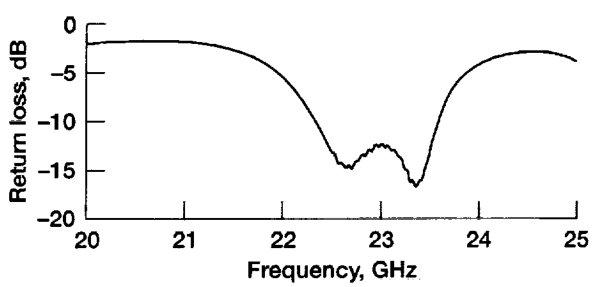

Figure 4.—Measured return loss of the four element array.

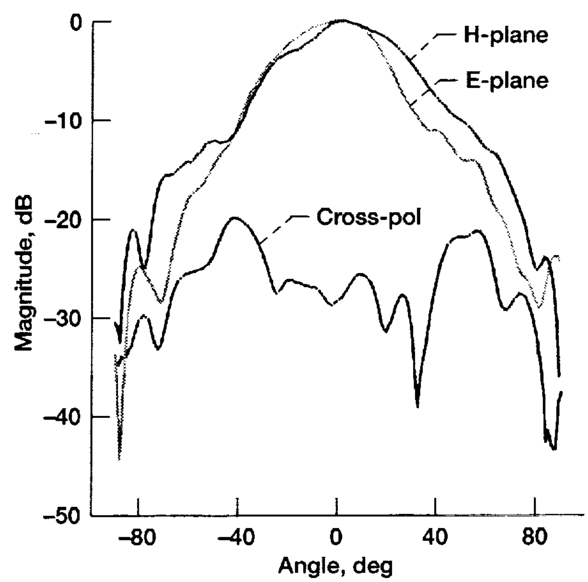

Figure 5.—Co-pol and cross-pol radiation patterns at 22.5 GHz.

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13. ABSTRACT ***(Maximum 200 words)***

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14. SUBJECT TERMS

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