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Multi-Technique Broadband Microstrip Patch Antenna Design

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Abstract—**Microstrip patch antennas offer low profile and small footprint advantages, but limited operating bandwidth. Substantial research focuses on broadband techniques. This paper presents the design, simulation, fabrication, and characterization of a 30% bandwidth microstrip patch antenna that incorporates multiple broadband techniques while minimizing footprint area. Methods include patch shape, dielectric thickness, and coupling slot optimization, with capacitively-coupled L-probe feeds.**

The final design incorporates an electrically thick dielectric and circular-E patch geometry. Microstrip L-probe feed and coupling slot dimensions were optimized via HFSS simulations. The final design was fabricated, and then tested in an anechoic chamber. The new design has measured and simulated impedance bandwidths (VSWR < 2) of 37.9% (7.9GHz to 11.6GHz) and 36.4% (8.1GHz to 11.7GHz), respectively. The minimum E- and H-plane measured main lobe gain is -3dBi from 7.9GHz to 9.0GHz, a 13.0% pattern bandwidth. The simulated pattern bandwidth is 11.8% (8.0GHz to 9.0GHz). Side lobe levels less than -4.7dB and a 3dB beamwidth of 15°±5° are maintained between 8.0GHz and 9.0GHz. At frequencies greater than 9.0GHz, the H-plane gain is less than -3dBi.

Keywords–Microstrip patch antenna; broadband techniques; patch antenna feed methods.

I. INTRODUCTION

Microstrip patch antenna advantages over other configurations include light-weight, low-cost, and mounting structure conformal geometry. Microstrip antennas also exhibit disadvantages: low power-handling capability, low gain, and narrow bandwidth. This paper combines and optimizes multiple broadband methods while minimizing footprint. Microstrip antenna operation and broadband techniques are reviewed, followed by simulation and parametric optimization. Final antenna construction is discussed; simulated and measured results are compared.

Electrically thick dielectrics increase bandwidth, but also introduce impedance matching challenges [1]. Probe feed inductance is proportional to dielectric thickness; hence, a capacitively-coupled feed is used to offset probe inductance.

Rectangular-E [2] and circular-E [3] patches achieve bandwidths of 30% and 26%, respectively. This paper describes the design of an X band (9.0GHz) microstrip antenna exhibiting an impedance bandwidth of over 30%.

II. MICROSTRIP BROADBAND TECHNIQUES

Microstrip antenna bandwidth is increased by dual-band patch shape selection; i.e.: E-shaped patch and U-shaped slot antennas, see Fig. 1. Low and high resonance frequencies are created by edge currents flowing around the slots and around the patch exterior, respectively.

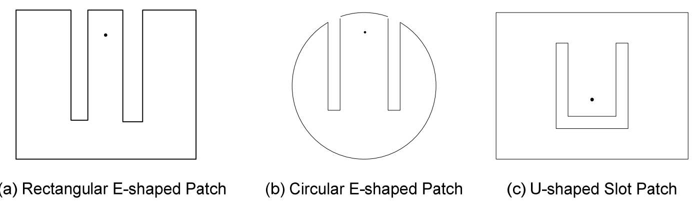

Fig. 1. Broadband Microstrip Patch Antenna Shapes.

Fig. 2 shows equivalent LC resonant circuits for rectangular E-shaped designs [2].

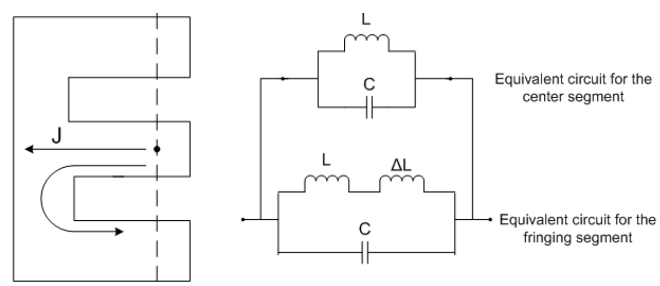

Fig. 2. Microstrip Patch Antenna Equivalent Circuit.

Patch antenna feed length and width were adjusted through HFSS simulations to maximize antenna impedance bandwidth, see Fig. 3. Feed dimensions affect induced capacitance to compensate for probe inductance. Slot length and width are directly proportional to the low resonance. Overall patch size was maintained to preserve operating frequency.

The L-probe feed is a 90° formed center conductor proximity coupled to the radiating patch (Fig. 4). The feed-patch gap creates a series capacitance which is directly proportional to the feed-patch dielectric thickness, L_g, and probe diameter, L_d, but inversely proportional to the under patch probe length, L_c. All dimensions were adjusted to cancel the probe inductance.

The dielectric embedded L-probe presents fabrication difficulties. This structure is realized with a lower (ground plane-probe) foam layer and an upper (probe-patch) microwave dielectric layer (ε_r = 2.2) to minimize patch size. Despite fabrication complications, the L-probe feed represents an important broadband technique.

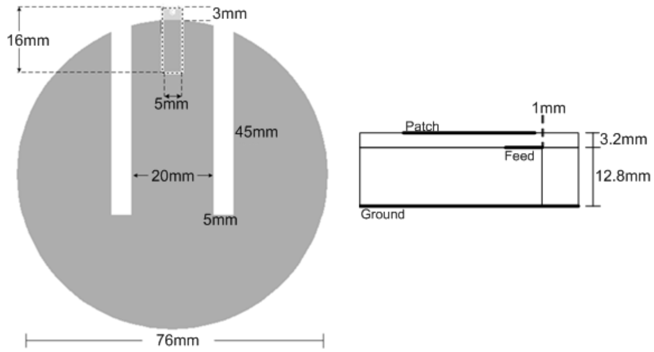

Fig. 3. Circular-E Patch [3] Optimized Dimensions.

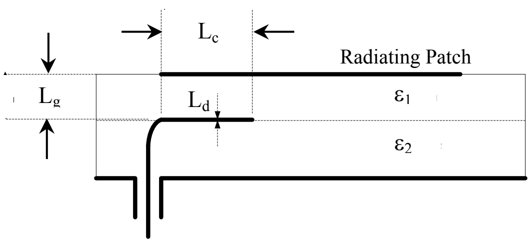

Fig. 4. Microstrip L-Probe Antenna Feed.

Patch geometry and feed structure combinations were simulated to identify the optimal design (Table I).

TABLE I. PATCH ANTENNA CONFIGURATION RESULTS.

Radiating Structure	Feed Method	Max Sim Bandwidth	Meas Center Freq (GHz)	Meas Ant Bandwidth
Circ-E, air	Coax	19%	8.7	7.7%
Rect-E, μwave	Coax	11%	8.5	10.0%
Rect-E, μwave	Coax	14%	8.8	8.8%
Circ-E, air	L-probe	28%	9.2	11.1%
Circ-E, μwave	L-probe	40%	9.9	11.1%

Notes: air = air dielectric, μwave = microwave dielectric

The selected design uses a circular-E patch, L-probe, and microwave dielectric. Simulated impedance bandwidth is 40%.

III. PATCH ANTENNA FABRICATION

The final design was converted to Gerber files for fabrication; the actual antenna appears in Fig. 5. The circular-E patch and rectangular microstrip feed were etched onto opposite sides of a 3.2mm thick EccoStock dielectric, plated on one side and drilled for feed placement. The two boards were combined with nylon screws, see Fig. 5.

IV. RESULTS AND COMPARISONS

Simulated and measured center frequency and impedance bandwidth results are shown in Table II. Simulated and measured E- and H-plane co-pol sidelobe levels (SLL) and 3dB beamwidths (3dB BW) are listed in Tables III and IV.

Maximum measured SLL occurs at 9.0GHz, E-plane: -4.7dB. The measured E-plane, 8.0GHz, 3dB BW is approximately half the corresponding simulated values (hence higher gain).

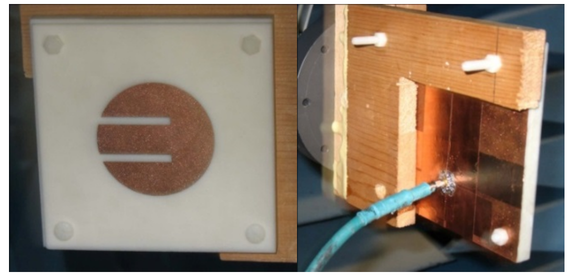

Fig. 5. Fabricated Circular-E Patch Antenna.

TABLE II. PATCH ANTENNA CENTER FREQUENCY AND BANDWIDTH.

	Center Frequency (GHz)	Impedance Bandwidth
HFSS (Simulated)	9.9	40.6%
Measured	9.7	41.1%

TABLE III. PATCH E-PLANE CO-POL SLL AND 3DB BWS.

	Simulated		Measured	
Freq (GHz)	SLL (dB)	3dB BW	SLL (dB)	3dB BW
8.0	-8.3	21.3°	-7.1	11.4°
9.0	-9.2	18.7°	-12.7	14.9°
10.0	-4.9	20.1°	-4.7	17.5°

TABLE IV. PATCH H-PLANE CO-POL SLL AND 3DB BWS.

	Simulated		Measured	
Freq (GHz)	SLL (dB)	3dB BW	SLL (dB)	3dB BW
8.0	-9.8	15.3°	-7.9	14.9°
9.0	-7.7	21.1°	-10.0	21.2°
10.0	-10.7	13.0°	-7.2	10.5°

V. CONCLUSIONS AND FUTURE WORK

A circular-E patch design with electrically thick dielectric and capacitive feed structure yields a 41.1% measured impedance bandwidth. Leaky slot [2] and spurious probe radiation [1] create large H-plane cross-pol radiation relative to E-plane values. Patch slots cause frequency-dependent E-plane mainlobe direction shifts. Radiation pattern frequency sensitivity limits overall antenna bandwidth to 12.3%.

Dielectric thickness should be decreased to reduce H-plane cross-pol radiation without decreasing impedance bandwidth. Other patch shapes should be explored along with alternate feed methods to improve performance.

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