Dual Polarized Microstrip Patch Antenna, Reduced in Size by Use of Peripheral Slits

Dimitris T. Notis, Phaedra C. Liakou and Dimitris P. Chrissoulidis

Aristotle University of Thessaloniki, Department of Electrical & Computer Engineering,
PO Box 1562, GR-54124, Thessaloniki, Greece;Tel./Fax: 30-2310-996334; dpchriss@auth.gr

***Abstract* — A two-port, meandered, square, microstrip patch antenna is investigated in this paper. Forty slits are considered on the perimeter of a square patch, ten on each side, to reduce the operating frequency. Calculated and measured results manifest that (a) the gain, the radiation patterns (co- and cross-polar), and the matching microstrip lines are practically unaffected by the peripheral slits, (b) the return loss at both ports is well below $-20dB$, and (c) the coupling between ports is below $-29dB$. A square patch, thus meandered, may be up to 48% smaller in area than a square patch without slits, both with the same operating frequency.**

I. Introduction

Microstrip patch antennas are widely used because of several attractive features, such as low cost, small weight, ease of fabrication, etc. Present-day applications require small antenna size even at low frequencies [1]. Effective methods to shrink a patch antenna are (a) by use of high-permittivity substrates, (b) by loading the patch with shorting pins, and (c) by meandering the ground plane or the perimeter of the patch [2,3]. The latter method is applied in this paper in conjunction with a two-port, square, microstrip patch antenna. Similar, compact, dual-polarized antennas have been discussed in [4], wherein four, bended slots have been embedded within the square patch to achieve smaller size. So far, the design proposed herein has achieved up to 48% reduction in size with 38% decrease in operating frequency; [4] reports 44% reduction in size with 25% reduction in operating frequency.

II. Antenna Design and Calculations

Fig. 1 shows a square patch with two feed lines and forty peripheral slits, ten on every side. The patch is printed on Taconic, TLY-5 laminate with relative permittivity $\varepsilon_r = 2.21$, thickness $h = 62mil$, and loss tangent $\tan\delta = 0.0009$. The ground plane is $3900mil \times 3900mil$ and the patch is $1620mil \times 1620mil$; the operating frequency is $2.36GHz$ without slits (i.e. $l = 0mil$). The feed lines end in the center of two adjacent sides, which ensures maximum port isolation [5]; this antenna operates in two linear, orthogonal polarizations, associated with the two ports. The input impedance of each port has been matched to the 50Ω microstrip feed lines by use of $\lambda_g/4$ transformers.

Each group of slits is symmetrically placed with respect to the center of the side where it belongs. The slits are narrow ($w = 20mil$), the spacing between adjacent slits is constant ($s = 40mil$) and the slit length l varies from $0mil$ to $380mil$.

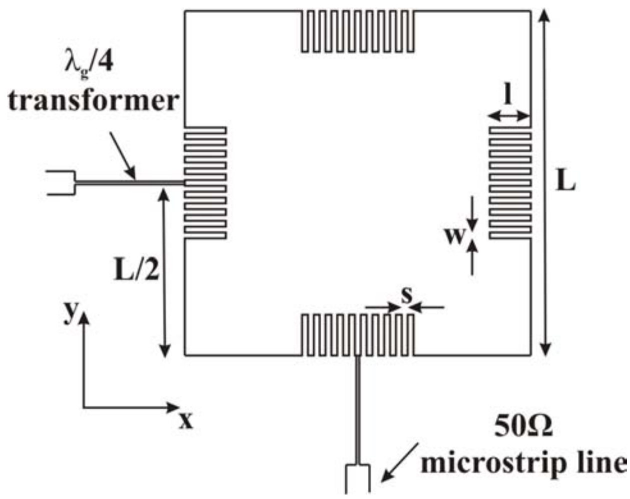


Fig. 1 Geometry of dual-polarized, meandered, square, microstrip patch antenna ($L = 1620mil$, $w = 20mil$, $s = 40mil$).

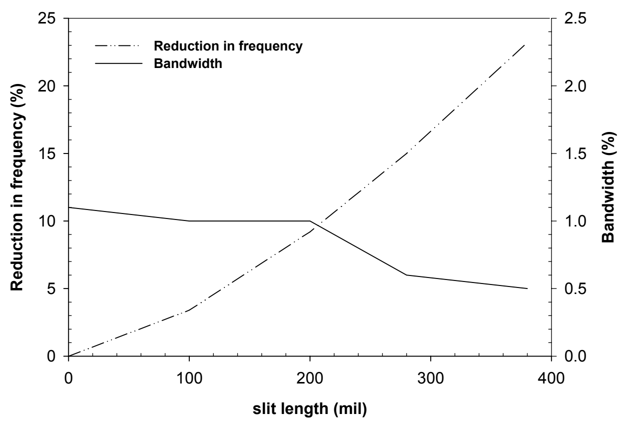


Fig. 2 $(1620 \times 1620)mil$ patch with 40 slits: reduction in operating frequency Δf_r (% re f_r for $l = 0mil$) and impedance bandwidth BW (% re f_r) versus slit length l.

The slits disturb the currents flowing on the surface, forcing them to meander and thus the electrical length of the patch antenna increases in both dimensions. Accordingly, the operating frequency decreases, whereas the physical size of the patch is unaffected, as illustrated in Fig. 2. By the same token, operation at a fixed frequency with reduced size is possible by increasing the slit length. This effect is depicted in Fig. 3, where slits of increasing length are introduced to the $(1620 \times 1620)mil$ patch and the reduction in size is calculated as percentage of the size of a square patch without slits and with the same operating frequency.

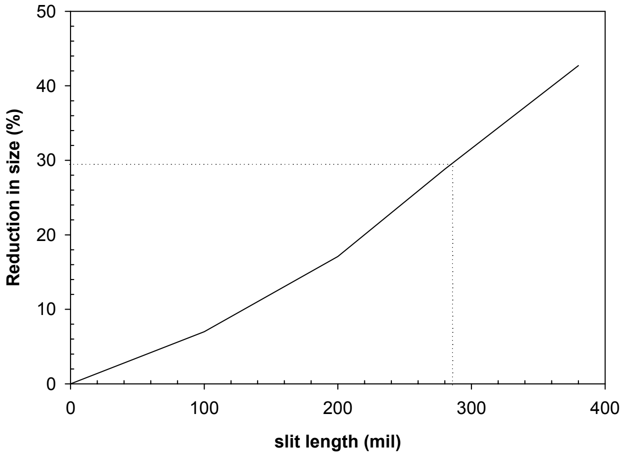
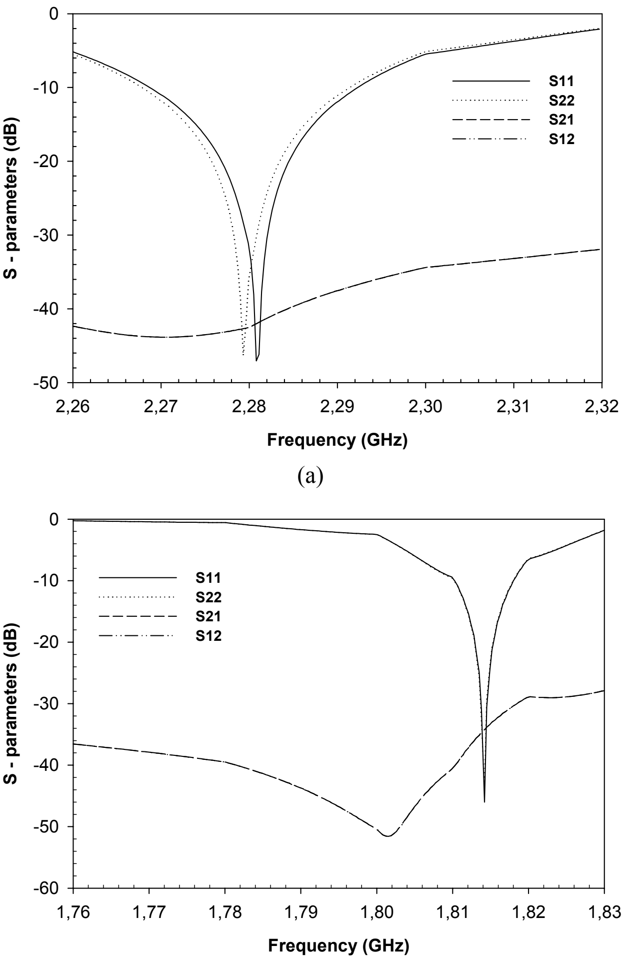


Fig. 3 $(1620\times1620)\,mil$ patch with 40 slits: reduction in size (% re size of patch without slits and the same f_r) versus slit length l.



(a)

(b)

Fig. 4 $(1620\times1620)\,mil$ patch with 40 slits: S-parameters versus frequency f for (a) $l=100\,mil$ and (b) $l=380\,mil$.

Furthermore, the impedance bandwidth (i.e. the $-10\,dB$ bandwidth) of the square patch decreases as the slit length increases, which is also depicted in Fig. 2. The bandwidth of the antenna without slits, which operates at $2.36\,GHz$, is 1.1% of this frequency, (i.e. $259.6\,MHz$). By introducing peripheral slits in the aforesaid patch, the bandwidth falls to $0.5\,\%$, (i.e. $90.5\,MHz$) of the reduced operating frequency, which is $1.81\,GHz$, with $l=380\,mil$. This degradation of the antenna bandwidth can be mitigated by use of various bandwidth enhancing techniques, such as vias or aperture coupled feeding.

Our calculations suggest that the dimensions of the matching microstrip lines at both ports are practically unaffected by the presence of slits. Hence, we have used microstrip lines of width $23\,mil$ and length $950\,mil$, which are appropriate for the reference $(1620\times1620)\,mil$ patch without slits. The calculated results of Fig. 4 manifest that (a) the return loss at either port is below $-40\,dB$ and (b) the coupling between ports is below $-35\,dB$. Other calculated results, not shown herein, indicate that the return loss may be worse than that of Fig. 4, but safely below $-20\,dB$ in any case.

As already mentioned above, surface currents are forced to flow around the groups of slits, which results in (a) lengthening of the electrical size of the patch in both dimensions and (b) emergence of currents which are normal to the direction of excitation. Hence, higher cross-polarization levels are expected. However, our calculations have shown that cross-polarization levels in the *E*- and *H*- planes are below $-30\,dB$, as illustrated in Fig. 5. Furthermore, the radiation patterns in the aforesaid principal planes remain broad. Finally, it should be noted than because of the reduction in size, the antenna bandwidth and the antenna gain are degraded, albeit marginally; the reduction in gain is less than $0.5\,dB$. The co-polar radiation patterns in both principal cuts are also shown in Fig. 5; the maximum antenna gain is equal to $7.1\,dBi$.

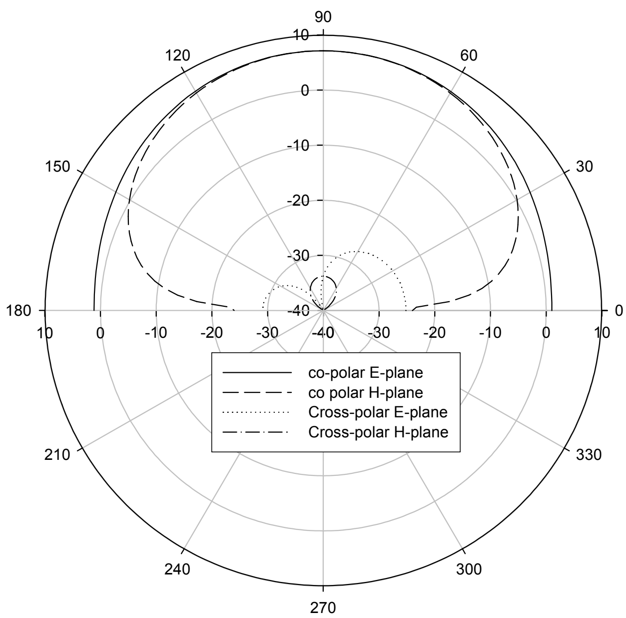


Fig. 5 $(1620\times1620)\,mil$ patch with 40 slits: calculated radiation patterns in *E* and *H*-plane (co- and cross-polarized); the average slit length on each side is $286\,mil$.

III. EXPERIMENTAL RESULTS

The predictions of Figs. 2, 3 and 4 have been verified by measurements made on a $1620mil \times 1620mil$ patch antenna with average slit length $l = 286mil$, which is expected to operate at $2GHz$. Every side accommodates six slits of length $290mil$ and four slits of length $280mil$, thus providing the average slit length of $286mil$.

This patch is 29% smaller in size than the reference patch without slits. The measured return loss is below $-28dB$ and the measured coupling between ports is below $-29dB$, both at $2GHz$, as shown in Fig. 6. Good agreement between calculations and measurements has been achieved.

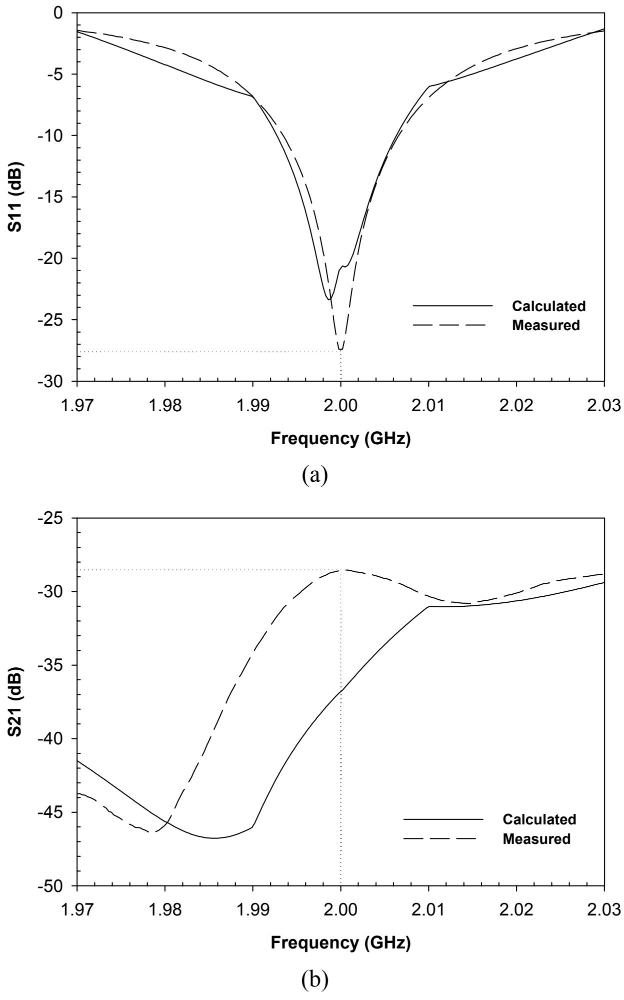


Fig. 6 $(1620 \times 1620)mil$ patch with 40 slits: input return loss (a) and coupling between ports (b); the average slit length on each side is $286mil$.

IV. DESIGN LIMITATIONS

It is important to examine the inherent limitations of the aforementioned design, with respect to the electrical characteristics of the antenna. Apparently, the first limitation arises by the fact that the slit length is constrained by the size selected for the initial square patch: (the slits on adjacent antenna sides should not overlap).

Furthermore, the electrical performance of the antenna may degrade, as the slit length increases, both in terms of input return loss and port isolation. To demonstrate this effect, three different square patch antennas were designed, each operating at $2GHz$, with average slit length $0mil$, $286mil$ and $354mil$ respectively. The input return loss for this parametric study is illustrated in Fig. 7. The overall size reduction achieved with the smallest design is 48%, with the operating frequency decreased by 38%; the return loss at the operating frequency remained below $-20dB$.

Additionally, as already shown before, peripheral slits in a square patch have a degrading effect on the impedance bandwidth. Fig. 8 manifests the interdependence between the reduction in operating frequency and the reduction in bandwidth for the three antennas of the aforementioned parametric study. The calculated bandwidth for the smallest design with average slit length $l = 354mil$ is 0.35%.

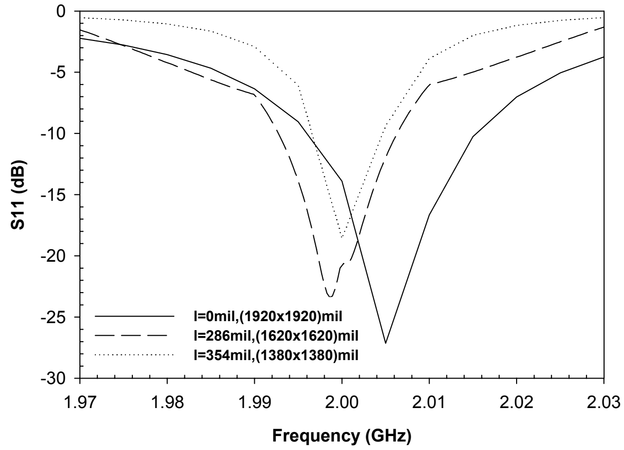


Fig. 7 Input return loss versus frequency f for three square patches, each with 40 slits; the average slit length on each side is $0mil$, $286mil$ and $354mil$; all three patches operate at $f_r = 2GHz$.

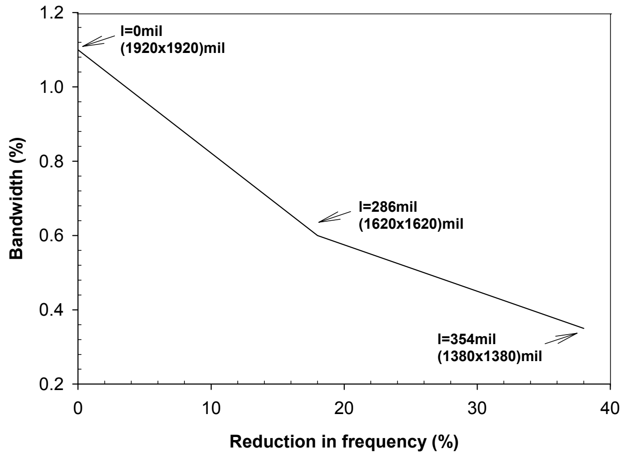


Fig. 8 Impedance bandwidth BW (% re f_r) versus reduction in operating frequency Δf_r (% re f_r for $l = 0mil$) for the square patches of Fig. 7.

In general, provided that the antenna has to meet certain electrical performance specifications (for return loss, isolation and impedance bandwidth), special care must be taken for the distribution of slits and the average slit length.

V. CONCLUSIONS

The proposed dual polarized antenna has achieved 48% reduction in size. The return loss remains at acceptable levels less than $-20dB$ and the isolation of ports is better than $29dB$. The impedance bandwidth exhibits some degradation, whereas all other features of the antenna are practically unaffected by the presence of slits.

Further improvement in size reduction is possible by use of more slits. To overcome certain limitations due to physical constrains of the slit length, it is possible to apply a tapering profile to the slit configuration.

REFERENCES

[1] A.K. Skrivernilk, J.F. Zurcher O. Staub and J.R. Mosig, "PCS antenna design: The challenge of miniaturization", *IEEE Antennas Propagation Magazine*, 43 (4), pp. 12-27, August 2001.

[2] K.L. Wong, *Compact and Broadband Microstrip Antennas*, Wiley, New York, 2002.

[3] X.X. Zhang and F. Yang, "The study of slit cut on the microstrip antenna and its applications," *Microwave & Optical Technology Letters* 18 (4), pp. 297-300, July 1998.

[4] G.S. Row, S.H. Yeh, and K.L. Wong, "Compact dual-polarized microstrip antennas", *Microwave & Optical Technology Letters*, 27 (4), pp. 284-287, November 2000.

[5] K.V.S. Rao and P. Bhartia, "Studies on input impedance and coupling of dual polarized two-port microstrip antenna", in *IEEE AP-S/URSI International Symposium Digest* 1989, pp. 608-611.