References

1 FARHAT, N. H., PSALTIS, D., PRATA, A., and PEAK, E.: 'Optical implementation of the Hopfield model', *Appl. Opt.*, 1985, **24**, pp. 1469–1475
2 FISHER, N. H., LIPPINCOTT, W. L., and LEE, J. N.: 'Optical implementations of associative networks with versatile adaptive learning capabilties', *Appl. Opt.*, 1987, **26**, pp. 5039–5054
3 FARHAT, N. H.: 'Optoelectronic analogs of self-programming and methodologies for implementing fast stochastic learing by simulated annealing', *Appl. Opt.*, 1987, **26**, pp. 5093–5103
4 KYUMA, K., MITSUNAGA, K., and OHTA, J.: 'Optical implementation of neural networks'. Proc. Interconnections and Neural Networks, The Hague, The Netherlands, March 1990, pp. 124–135
5 HOPFIELD, J. J.: 'Neural networks and physical systems with emergent collective computational abilities'. Proc. Natl. Acad. Sci. USA, 1982, **79**, pp. 2554–2558
6 RUMELHART, D. E., MCCLELLAND, J. E., and PDP Research Group: 'Parallel distributed processing' (MIT Press, Cambridge, Mass., 1986), Vol. 1
7 NITTA, Y., OHTA, J., MITSUNAGA, K., TAKAHASHI, M., TAI, S., and KYUMA, K.: 'GaAs/AlGaAs optical interconnection chip for neural network', *Jpn. J. Appl. Phys.*, 1990, **26**, pp. L2101–2103
8 OHTA, J., TAKAHASHI, M., NITTA, Y., TAI, S., MITSUNAGA, K., and KYUMA, K.: 'GaAs/AlGaAs optical synaptic interconnection device for neural networks', *Opt. Lett.*, 1989, **14**, pp. 844–846
9 SUN, C. C., WIEDER, H. H., and CHANG, W. S. C.: 'A new semiconductor device—the gate controlled photodiode: device concept and experimental results', *IEEE J. Quantum Electron.*, 1989, **QE-25**, pp. 896–903
10 SCHNEIDER, M. V.: 'Schottky barrier photodiodes with antireflection coating', *Bell Syst. Tech. J.*, 1966, **45**, pp. 1611–1638
11 SZE, S. Z.: 'Physics of semiconductor devices' (Wiley-Interscience, New York, 1981), Chap. 6, 2nd edn.

EFFECT OF DIELECTRIC PROTECTING SUPERSTRATE ON RADIATION PATTERN OF MICROSTRIP PATCH ANTENNA

Indexing terms: Antennas, Dielectrics and dielectric devices, Microstrip

The effects of a protecting dielectric superstrate on the radiation pattern of an X-band rectangular microstrip patch antenna have been studied experimentally. Results indicate that although, at higher substrate thicknesses, the resonance frequency does not shift further, the radiation pattern drastically changes into two or three lobes, depending on superstrate thickness.

Introduction: It is known that environmental elements (such as snow, raindrops, etc.) or even the dielectric protecting superstrate cause changes in the resonance frequency f_r of a microstrip patch antenna (MPA) and its reflection coefficient Γ. To overcome this problem, different solutions have been suggested in the literature, such as increasing impedance bandwidth[1–3] or using thick superstrate to reduce further changes due to unexpected environmental elements.[4]

Although such reports about changes in f_r with in-touch superstrate are available,[4–5] there is no experimental report on the effects of superstrate on the radiation pattern of an MPA. The only related report is on a printed dipole embedded in dielectric, which indicates splitting of the mainlobe into two or three lobes with an increase in superstrate thickness.[6]

This Letter presents the experimental results of using a dielectric superstrate ($\theta_r \simeq 2{\cdot}6$) on a rectangular MPA with different thicknesses up to about half a wavelength. Observations show that the dielectric protecting superstrate not only changes the f_r and Γ of a rectangular MPA, but also causes drastic changes in the shape of the radiation pattern at higher thicknesses.

Experimental results: A rectangular MPA is designed using the modal expansion cavity model,[7] fed with microstripline. It is fabricated on alumina substrate ($\theta_r = 9{\cdot}8$, $h = 0{\cdot}635$ mm and $\tan\delta = 0{\cdot}0001$) with thin film technology and optical lithography. The patch width and resonant length are 7·95 mm and 4·58 mm, respectively.

The radiation pattern is measured using a motor-driven positioner and a synchronised x-t recorder. The power is fed to the patch at the corresponding resonance frequencies (see Table 1) when the superstrate is used on the patch.

In this work, only H-plane radiation patterns are studied. A square perspex superstrate 51 × 51 mm is used (which is about 10 times the patch size), with various relative thicknesses up to $0{\cdot}58\lambda_m$, where $\lambda_m = \lambda_0/\sqrt{(\theta_r)}$ (λ_0 is the free space wavelength). Fig. 1 shows the observed radiation patterns without superstrate and with superstrate up to $d = 0{\cdot}58\lambda_m$ and some critical parameters are given in Table 1. With thin superstrate, the radiation pattern broadens and the lobe amplitude at zero degrees (A_n) falls with respect to that of the patch without superstrate. With further increase in d, the radiation pattern split into two symmetric lobes for $d = 0{\cdot}35\lambda_m$ and then into three lobes of nearly equal amplitude for $d = 0{\cdot}52\lambda_m$, which finally gives three lobes having the centre lobe higher than for the other two lobes for $d = 0{\cdot}58\lambda_m$. This splitting is possibly related to the superstrate being in the electrostatic zone of an

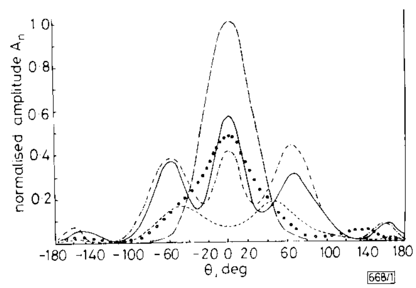

Fig. 1 *Behaviour of radiation pattern of rectangular MPA with increase in thickness of superstrate*

H plane
d/λ_m
— — 0·00
○○○ 0·14
- - - - 0·35
—·—· 0·52
——— 0·58

Table 1 RECTANGULAR MPA PARAMETERS WITH IN-TOUCH PROTECTING PERSPEX SUPERSTRATE

Superstrate relative thickness (d/λ_{mo})	Resonance frequency f_r	Voltage reflection coefficient Γ	Number of lobes	Angle of lobes	Normalised amplitude of dominant lobe (A_n)*
	GHz			deg	
0·00	9·76	0·36	1	0	1·00
0·14	9·55	0·63	1	0	0·48
0·35	9·60	0·65	2	±47	0·18
0·52	9·61	0·62	3	0, ±62	0·40
0·58	9·61	0·58	3	0, ±60	0·58

* A_n = Amplitude with superstrate/amplitude without superstrate.

MPA and generating more surface waves. It can be seen from Table 1 that for $d > 0{\cdot}14\lambda_m$ the f_r and Γ give practically no further shifts, therefore at higher thicknesses the amplitudes of the lobes are not related to variations in Γ.

However the use of superstrate at higher thickness drastically changes the shape of radiation pattern in addition to the f_r and Γ changes. This has to be taken into consideration when the superstrate is used on an MPA.

Conclusions: The present experimental work shows that using thick superstrate as a protecting layer may not give further changes in f_r and Γ but will drastically change the shape of radiation pattern into two and three lobes depending on the thicknesses of superstrate. Therefore when superstrate is used in-touch with a patch, an optimised thickness ($\leq 0{\cdot}14\lambda_m$) is suggested. Higher thicknesses of superstrate can be used to split the mainlobe of a single microstrip patch antenna into two or three lobes for special purposes.

Acknowledgments: Authors would like to thank S. A. Gangal and R. C. Aiyer for their kind help during the work, and USIC for fabrication of the positioner.

25th April 1991

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References

1 SANFORD, G. G.: 'Multiple resonance radio frequency microstrip antenna structure'. US Patent 4070676, 1978
2 HENDERSON, A., JAMES, J. R., and HALL, C. M.: 'Bandwidth extension technique in printed conformal antennas', *in* CLARRICOATS, P.: 'Advanced antenna technology Vol. 2' (Microwave Exhibitions and Publishers Ltd., Tunbridge, Kent, 1987), pp. 141–146
3 BHATNAGAR, P. S., DANIEL, J. P., MAHDJOUBI, K., and TERRET, C.: 'Displaced multilayer triangular elements widen antenna bandwidth', *Electron. Lett.*, 1988, **24**, pp. 962–964
4 BAHL, I. J., BHARTIA, P., and STUCHLY, S. S.: 'Design of microstrip antennas covered with a dielectric layer', *IEEE Trans.*, 1982, **AP-30**, (2), pp. 314–318
5 BHATTACHARYYA, A., and TRALMAN, T.: 'Effect of dielectric superstrate on patch antennas', *Electron. Lett.*, 1988, **24**, (6), pp. 356–358
6 KATEHI, P. S., and ALEXOPOULOS, N. G.: 'On the effect of substrate thickness and permittivity on printed circuit dipole properties', *IEEE Trans.*, 1983, **AP-31**, (1), pp. 34–39
7 CARVER, K. R., and MINK, J. W.: 'Microstrip antenna technology', *IEEE Trans.*, 1981, **AP-29**, (1), pp. 2–25

ERRATA

Authors' corrections

BERWICK, M., PANNELL, C. N., RUSSELL, P. ST. J., and JACKSON, D. A.: 'Demonstration of birefringent optical fibre frequency shifter employing torsional waves', *Electron. Lett.*, 1991, **27**, (9), pp. 713–715

In both parts of Fig. 3, the vertical scale is 5 dB/division and the upper limit of the vertical axis is −50 dBm

Printers' corrections

EDGCOMBE, C. J.: 'Measurement of surface resistance of high-T_c superconductor by use of dielectric resonator', *Electron. Lett.*, 1991, **27**, (10), pp. 814–816

This Letter was received on *27th February 1991*

VIDIMARI, F., CALDIRONI, M., DI PAOLA, A., CHEN, R., and PELLEGRINO, S.: 'Semi-insulating layers in InP obtained by Co or Fe ion implantation', *Electron. Lett.*, 1991, **27**, (10), pp. 817–818

This Letter was received on *26th February 1991*

HO, S., and LAW, P.: 'Efficient hardware decoding method for modified Huffman code', *Electron. Lett.*, 1991, **27**, (10), pp. 855–856

This Letter was received on *12th December 1990*

DODD, P. E., LOVEJOY, M. L., MELLOCH, M. R., and LUNDSTROM, M. S.: 'Cryogenic operation of GaAs bipolar transistors with inverted base doping', *Electron. Lett.*, 1991, **27**, (10), pp. 860–861

This Letter was received on *12th February 1991*

HUNTER, C. A., CALTON, R. L., SADD, P. R., and WALKER, S. D.: 'Optical feedback receiver with sensitivity of −55·2 dBm at 8 Mbit/s', *Electron. Lett.*, 1991, **27**, (10), pp. 886–887

This Letter was received on *4th March 1991*