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New compact microstrip antenna

J. George, M. Deepukumar, C.K. Aanandan, P. Mohanan and K.G. Nair

Indexing terms: Microstrip antennas, Antennas

A new microstrip antenna geometry with considerable reduction in size, with similar radiation characteristics to those of an equivalent rectangular patch antenna is proposed. A relationship has been suggested for finding out the resonant frequency of the new geometry, and its validity has been established by the experimental results. Without increasing the aperture area, this geometry also offers a facility for considerably reducing the resonant frequency compared to conventional patches.

Introduction: Owing to their unique and attractive properties such as light weight, low profile, conformal nature and low production costs, microstrip antennas are fast replacing conventional antennas. Although rectangular and circular geometries are the most commonly used ones, other geometries are also considered, depending on the application. There are a number of techniques for increasing the resonant frequency of a microstrip antenna [1 – 3], but very few for reducing the same. One method is to introduce some perturbation in the cavity below the patch [4]. This method is actually compromising the conformal nature of the antenna. Another method is by shorting the electric field at the null point [5]. In this Letter we present a new geometry for a patch antenna with reduced size which will give a lower resonant frequency by slight modification of the patch geometry (without increasing the overall patch area). An empirical formula, which can predict the resonant frequency of the new structure, with an error of <4%, is also presented, and its validity has been established.

Design, experimental and theoretical details: The schematic diagram of the antenna is shown in Fig. 1. The structure consists of a drum shaped patch etched on a dielectric substrate of thickness h = 0.16cm and dielectric constant ϵ_r = 4.5. The feed point is specified in terms of the co-ordinates (X_0, Y_0).

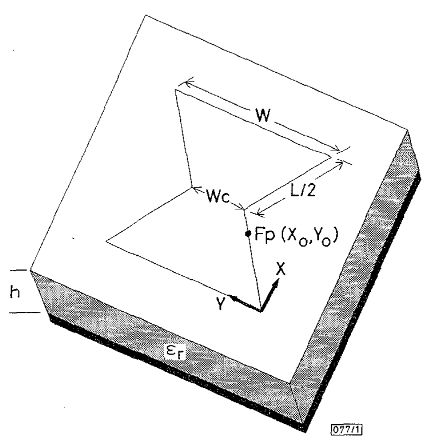

Fig. 1 *Geometry of proposed microstrip antenna*

The resonant frequency of the antenna is found to be decreasing with a decrease in W_c. It is also noted that, for a particular value of W_c, resonant frequency reduces with increase in the irregular side length L. The resonant frequency of the modified structure for the TM_{10} mode is calculated by modifying the standard equation for a rectangular patch antenna [6] as given below:

$$f_r = \frac{c}{2\sqrt{\epsilon_e}L}\left(\frac{1.152}{R_t}\right) \quad (1)$$

where

$$R_t = \frac{L}{2}\frac{[(W+2\Delta l)+(W_c+2\Delta l)]}{(W+2\Delta l)(S+2\Delta l)}$$

$$\Delta l = \frac{h0.412(\epsilon_e+0.3)\left(\frac{W_i}{h}+0.262\right)}{\left[(\epsilon_e-0.258)\left(\frac{W_i}{h}+0.813\right)\right]}$$

$$\epsilon_e = \left(\frac{\epsilon_r+1}{2}\right)+\left(\frac{\epsilon_r-1}{2}\right)\left(1+\frac{12h}{W_i}\right)^{-1/2}$$

$$W_i = \frac{W+W_c}{2}$$

where S is the separation between the two parallel sides of the antenna and c is the velocity of light in free space.

The theoretical variations of the resonant frequency with L for different values of W_c are given in Fig. 2, and are in good agreement with experimental results.

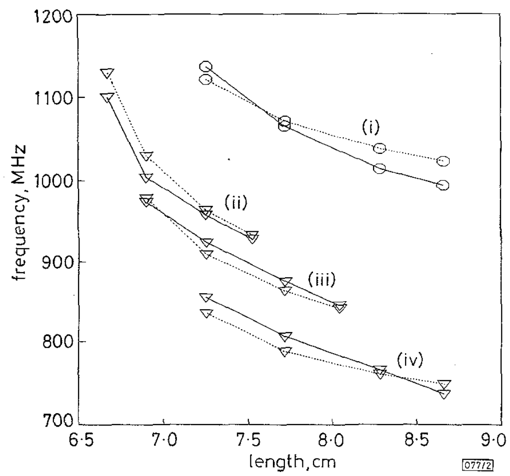

Fig. 2 *Variation of TM_{10} mode resonant frequency of antenna with length L for different W_c values*

——— experiment (∇; ϵ_r = 4.5, h = 0.16cm and O; ϵ_r = 2.22, h = 0.08cm)
– – – – theory (∇; ϵ_r = 4.5, h = 0.16cm and O; ϵ_r = 2.22, h = 0.08cm)
(i) W_c = 1cm (ii) W_c = 3cm (iii) W_c = 2cm (iv) W_c = 1cm

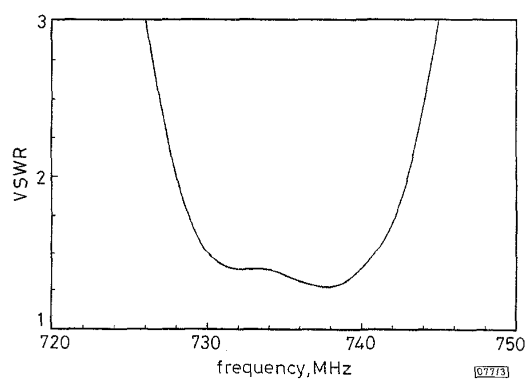

Fig. 3 *Variation of VSWR with frequency for X_0 = 2.6cm and Y_0 = 2.2cm*

The variation of the VSWR with frequency for a typical antenna structure with W = 6.6, W_c = 1 and L = 8.657cm is shown in Fig. 3. The antenna is found to be resonating at 737MHz (TM_{10} mode) and the 2:1 VSWR bandwidth is found to be 15MHz when the feed point F_p is at (2.6cm, 2.2cm). The E-plane and H-plane radiation patterns of the antenna for the TM_{10} mode are given in Fig. 4. The cross-polar performance of the antenna is found to be better than 20dB in both cases. The antenna is offering identical beamwidth along both the E-plane and H-plane, and hence is highly suitable as a feed for symmetric reflectors. For performing a comparative study, a rectangular patch antenna resonating at the same frequency has been fabricated on the same substrate. The directivity of the newly developed antenna is 5.25dB and is comparable to that of the rectangular patch antenna. The different antenna characteristics are compared and given in Table 1.

Table 1: Comparison of characteristics of new drum shaped antenna and rectangular patch antenna

	Antenna characteristic	New antenna	Rectangular patch
(i)	Resonant frequency corresponding to TM_{10} mode	737MHz	737MHz
(ii)	VSWR bandwidth ≤ 2	15MHz	16MHz
(iii)	3dB beamwidth (deg)		
	E-plane	90	99
	H-plane	92	83
(iv)	Directivity	5.25dB	5.83dB
(v)	Overall area	43.56sq.cm	117.55sq.cm

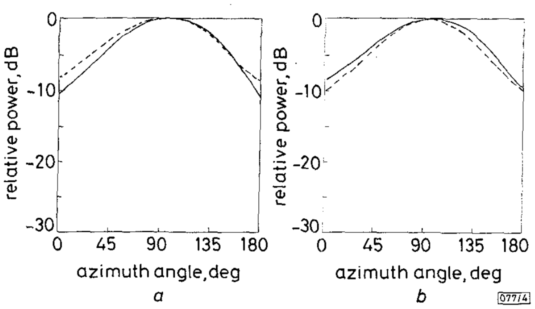

Fig. 4 *E-plane and H-plane radiation patterns of TM_{10} mode and TM_{01} mode*

a E-plane *b* H-plane
——— TM_{10} mode
- - - - TM_{01} mode

The main advantage of the new antenna is the reduction in size compared to a rectangular patch antenna for the TM_{10} mode (due to lowering of the resonant frequency). The reduction in resonant frequency is due to enhancement in the length of the antenna as confirmed by the theoretical analysis. The antenna is also resonating in the TM_{01} mode at 1.58GHz, as in the case of a rectangular patch antenna. Here the radiation is along the broad side direction with an enhanced gain as expected. Typical E-plane and H-plane radiation patterns of the antenna for TM_{01} mode are also given in Fig. 4. The narrow impedance bandwidth of the antenna can be enhanced by using conventional techniques applicable for rectangular microstrip antennas.

Conclusion: A new compact antenna geometry with a method for lowering the resonant frequency and having comparable characteristics with a standard rectangular patch antenna has been developed. The overall reduction in the area of the new antenna is >60% of a corresponding rectangular patch antenna. A theoretical relationship has been developed for calculating the resonant frequency of the new antenna. This may find applications in planar phased arrays, where array size is a major concern.

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Polarisation agile active microstrip patch arrays

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Indexing terms: Active antenna arrays, Microstrip antenna arrays

Two three-element polarisation-agile active microstrip patch arrays have been developed. The radiating elements are square patches each with two transistors mounted on adjacent edges. The patches radiate orthogonal modes, the relative phase of which can be varied. Radiation patterns show good agreement with predictions from theory, in both linear and circular polarisation, and no grating lobes were observed.

Introduction: In [1] we demonstrated polarisation agility in an antenna comprising two injection-locked diode-tuned printed oscillators, radiating orthogonal components. However, this arrangement is impractical for array applications owing to the noncoincident location of the phase centres of the radiated components, and its inefficient use of substrate space, limiting the number of possible configurations wherein grating lobes are suppressed. Therefore a compact polarisation-agile antenna element was developed to overcome these limitations [2]. Here we report results of measurements performed on two types of three-element array using these compact polarisation-agile elements.

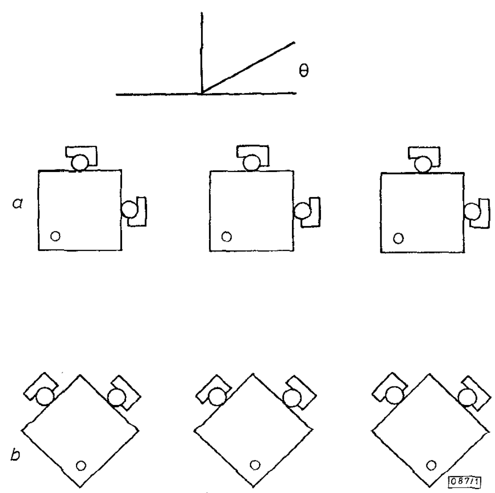

Fig. 1 *Array geometry*
Constructional details of elements as in [2]