Multifrequency Microstrip Patch Antenna Using Multiple Stacked Elements

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***Abstract*—A multifrequency microstrip patch antenna comprised of a driven patch and a plurality of parasitic elements placed underneath a driven patch is proposed. The antenna features a multifrequency behavior (five operating band) with similar gain.**

***Index Terms*—Microstrip antennas, multifrequency behavior, parasitic elements.**

I. Introduction

MULTIFREQUENCY antennas are attractive solutions when several operating systems have to present similar radiation performances(bandwidth, gain, and radiation pattern, for example). Sometimes, in order to cover several operating frequencies, a broadband antenna solution is proposed [1]. Although this technique is simple, radiation pattern and gain usually vary across the band. On the other hand, a broadband solution is sometimes a drawback because the antenna receives other nondesired frequencies and some kind of a filtering network is needed to cancel such frequency range. In this sense, a multifrequency antenna solution focuses only on the frequencies of interest. The present letter is focused on designing a multifrequency antenna using microstrip radiators.

Some attempts to design multifrequency microstrip patch antennas (MPAs) appear in the literature by means of adding parasitic patches as in [2], where a two-dimensional (2-D) coplanar configuration formed by aperture-coupled resonators is proposed to achieve three operating bands with a frequency ratio of $f_2/f_1 = 1.163$, $f_3/f_2 = 1.164$ with different bandwidths at each band (7.2%, 1.9% 1.1%, $S_{11} = 10$ dB). Other attempts use reactive structures bases on stub-loaded MPA where dual and triple frequency behavior is achieved. Frequency ratio using this technique is around 1.35 [3], [4]. In the present letter, the concept of multifrequency MPAs is applied employing multiple parasitic patches placed at different height under a driven patch (Fig. 1).

The main advantages of the present antenna is that several bands with similar bandwidth and gain are obtained [5]. A pentaband antenna using the geometry of Fig. 1 is numerically designed, built, and tested experimentally.

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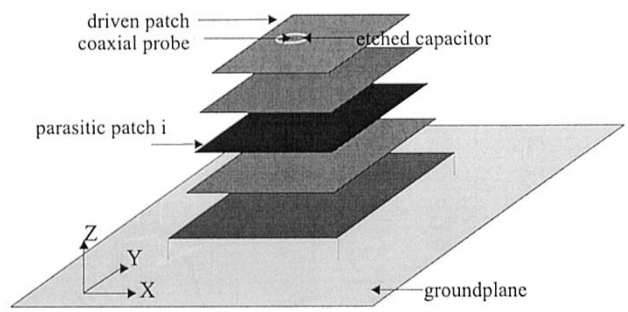

Fig. 1. Multifrequency MPA using a multiple-stacked structure formed by one driven patch and several parasitic patches.

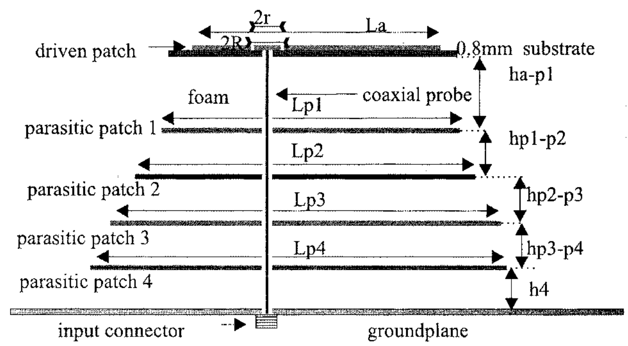

Fig. 2. All patches are square-shaped. $La = 51$, $Lp1 = 65$, $Lp2 = 70$, $Lp3 = 75$, $Lp4 = 80$, $ha - p1 = 6$, $hp1 - p2 = 2$, $hp2 - p3 = 2$, $hp3 - p4 = 2$, $h4 = 2$. Inner radius of the etched capacitor $r = 3.6$; outer radius $R = 4.7$. Feeding point is placed 13 mm from the driven patch center. Patch centers are aligned. All dimensions are in millimeters.

II. Experimental Results

A multistacked structure formed by four parasitic patches and one driven patch has been designed numerically using the commercial IE3D MoM-based code and it has been experimentally tested.

Fig. 2 shows the profile of such multistacked structure. The driven patch is fed by a coaxial probe through an etched capacitor. This etched capacitor cancel the high inductive effect of the coaxial probe and, thus, the antenna can be properly matched to the reference impedance of 50 Ω. The driven patch is etched on a thin substrate of $h = 0.8$ mm and $\varepsilon_r = 3.38$. Such driven patch is separated respect the nearest parasitic patch by using a foam substrate ($\varepsilon_r = 1.03$). Parasitic elements are brass-made of 0.2-mm thickness and they are separated using the above mentioned foam substrate. A hole of 2 mm diameter is practiced on the parasitic patches to avoid the contact with the feeding probe. Parasitic patch separation is 2 mm and separation between the driven and the closest parasitic patch is 6 mm. Hence,

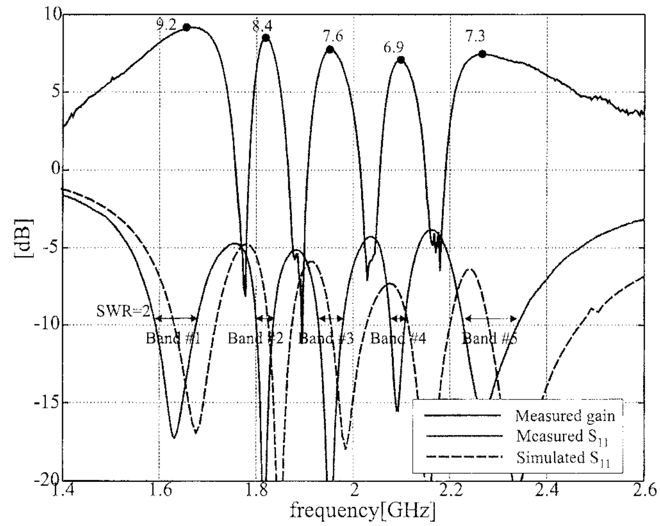

Fig. 3. Measured/simulated return loss and measured gain ($\theta = 0°$).

TABLE I
BW AND GAIN EXPERIMENTAL RESULTS

Band	f_o[GHz]	BW(SWR=2)[%]	Gain[dB]	$\frac{f_i}{f_0}$
1	1.634	5.5	9.2	-
2	1.819	2.0	8.4	1.113
3	1.954	2.7	7.6	1.195
4	2.092	1.5	6.9	1.280
5	2.289	5.3	7.3	1.4

the total antenna height is 15.6 mm. Groundplane dimensions are 220 × 180 mm.

After some antenna adjustments, the antenna has been matched and return loss and gain have been measured. Fig. 3 shows the experimental results as well as the computed result for return loss. It is observed that return loss measurement is shifted to lower frequencies with respect to those simulated; this is due to a slight compression of the soft substrates (foam) used to space the patches. If foams are slightly compressed, the dielectric constant increases causing a diminution of the measured resonant frequencies respect the predicted by the simulations. BW is around 5% (SWR = 2) for the first and last operating band and around 2% for the middle bands. Gain at $\theta = 0°$, which is the direction of maximum radiation after the numerical simulation results, varies from 7 to 9 dB, approximately. Table I summarizes the results for the central frequency operation (f_i), bandwidth, gain and frequency ratios.

It is interesting to calculate the gain drop across the impedance BW, that is, at frequencies where SWR = 2. Such gain drop is shown in Table II. The maximum gain drop is 2.2 dB for the second band while it is around 1 dB for the other bands.

Finally, radiation patterns are computed at the central frequency of each band in order to see the multifrequency behavior (Fig. 4). It can be observed that radiation patterns are similar, and especially in the H-plane. The simulated cross-polarized field is under −30 dB in the E-plane; for the H-plane, the cross-polar field increases, although for the broadside direction, it is kept under −30 dB, resulting in a high purity linear-polarized antenna.

TABLE II
GAIN AT FREQUENCIES WHERE SWR = 2. DROP IS THE MAXIMUM DROP GAIN RESPECT THE MAXIMUM GAIN IN THE BAND

Band	Gain f_{left}[dB]	Gainf_{right}[dB]	Drop[dB]
1	7.9	9	1.3
2	6.2	7.4	2.2
3	6.1	6.1	1.5
4	5.9	6.6	1
5	6.5	6.9	0.8

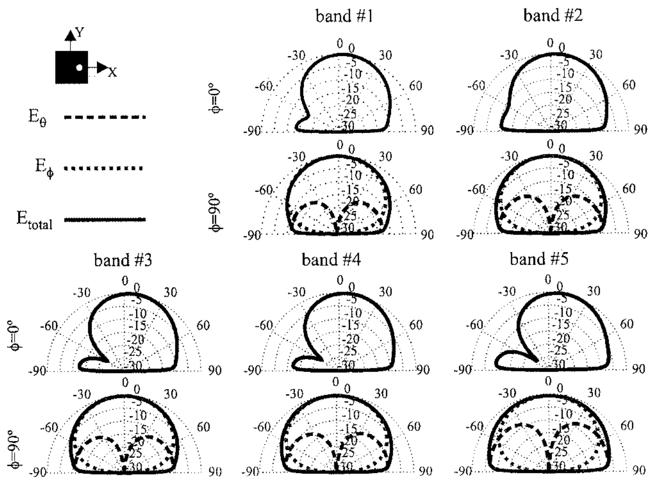

Fig. 4. Simulated main cuts at the central frequency of each operating band (see Table I).

III. CONCLUSION

A multifrequency patch antenna, formed by stacking several parasitic elements underneath a driven patch, has been proposed.

An experimental prototype has been designed achieving a pentaband behavior. Bandwidth at each operating band varies from 5% (SWR = 2) for the first and last band and it is around 2% for the middle bands. Gain has been measured obtaining a minimum gain of 6.9 dB and a gain drop across the band between 1 and 2 dB.

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