

# Wideband Stacked Microstrip Antenna

Slavi R. Baev<sup>1</sup>

**Abstract** – New configuration of stacked microstrip antenna is proposed in order to enhance its bandwidth. Additional parasitic elements - microstrip dipoles - are introduced in antenna construction in order to excite more resonances in frequency characteristic. Numerical and experimental comparison between proposed and typical stacked antenna is conducted and derived results are presented in the paper.

**Keywords** – microstrip antenna, bandwidth, parasitic dipoles.

## I. INTRODUCTION

Microstrip antennas are preferable type of radiator for many communications purposes. Some typical applications are: antennas for compact mobile terminals (GSM, GPS), wireless radio links, large antenna arrays with radiation pattern control for satellite communications. There is tendency in communication systems to decrease physical size of mobile devices and increase their functionality. Therefore antenna system should be small and should have wide frequency band. Wide bandwidth allows integration of different services and higher capacity in a mobile system.

Widespread method for bandwidth enhancement is excitation of multiple resonances in the impedance characteristic of the antenna by introduction of parasitic elements [1]. Parasitic elements can be placed in horizontal direction (planar configuration) [2], [3] or in vertical direction (stacked configuration) [4], [5] compared to the main radiator.

Combination of horizontally and vertically aligned radiating elements to achieve compact microstrip antenna with improved bandwidth is applied in [6], [7]. These publications present modified construction of aperture-coupled stacked microstrip antenna, which exhibits wider bandwidth compared to typical antenna of this type. In the proposed antenna two pairs of microstrip dipoles with different size are placed above the main radiator, instead of one wide rectangular patch. In this way two additional resonances are introduced in the impedance characteristic, instead of one.

In the present publication the idea used in [6] and [7] is further developed in order to explore the potential of the proposed method for bandwidth improvement. New antenna configuration is presented which exhibits three resonances in its characteristic similar to the radiator from [6] and [7]. In proposed antenna there is main patch on bottom substrate, parasitic patch on top substrate and two parasitic dipoles positioned adjacent to the main patch. Proposed stacked microstrip antenna is compared with typical one through simulations and experiment.

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## II. ANTENNA GEOMETRY

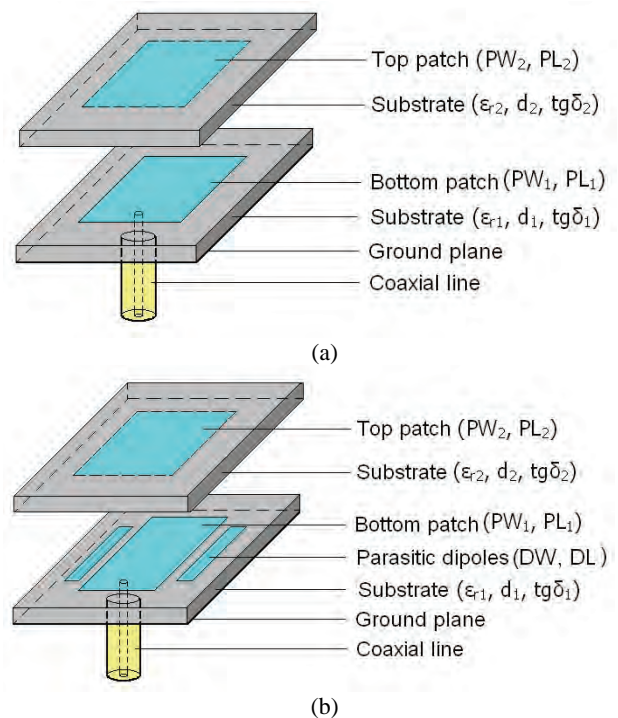


Fig. 1. 3D view of investigated antennas: (a) typical antenna (Antenna 1); (b) proposed antenna (Antenna 2)

Fig.1 presents typical stacked microstrip antenna (Antenna 1 – Fig.1a) and proposed stacked radiator (Antenna 2 – Fig.1b).

Coaxial line is used as feeding method in both antennas. It is convenient because there is no strong back radiation compared to aperture coupling method (microstrip line exciting bottom patch through slot cut in ground plane). Another problem with aperture feed is also omitted with coaxial line. In certain cases aperture may act as separate resonator and additional resonances may occur in frequency characteristic of the antenna. With coaxial feed resonances are formed only by the radiating elements above the ground plane. In this way the effects of main and parasitic patches can be clearly seen and evaluated.

The two antennas shown in Fig.1 have similar vertical structures. Directly fed main patch is formed on dielectric substrate with thickness  $d_1=0,81\text{mm}$  while top parasitic patch is formed on the bottom side of substrate with thickness  $d_2=0,508\text{mm}$ . RO4003 ( $\epsilon_r=3,38$ ) is used as dielectric material of the substrates. Additional air gap  $d_a$  separates top and bottom substrates providing proper element coupling. Dielectric spacers positioned in the four corners of the antenna element ensure this air gap.

Table 1 contains main construction parameters of two antennas. Designations are as follows:

$PL_i, PW_i$	Length and width of the patches,
$\epsilon_{ri}, d_i, tg\delta_i$	Relative dielectric permittivity, thickness and loss tangent of the substrate materials,
$DL, DW$	Length and width of the two microstrip dipoles,
$S$	Spacing between bottom patch and parasitic dipole.

TABLE I  
CONSTRUCTION PARAMETERS OF INVESTIGATED ANTENNAS

Designation	Value	
	Antenna 1	Antenna 2
$PL_1$	5,65 mm	5,65 mm
$PW_1$	5,15 mm	4,55 mm
$PL_2$	6 mm	5,8 mm
$PW_2$	6,5 mm	6,1 mm
$DL$	–	5,15 mm
$DW$	–	1,275 mm
$S$	–	0,2 mm
$d_1$	0,81 mm	0,81 mm
$d_2$	0,508 mm	0,508 mm
$d_a$	1,7 mm	2,1 mm

In typical stacked microstrip antenna (Fig.1a) coaxial line feeds bottom patch and top patch is excited through electromagnetic coupling with bottom element. The two elements have slightly different geometrical sizes and therefore resonate at adjacent frequencies. Therefore in VSWR or return loss characteristics only two clear resonances are observed. They overlap in a way that forms wide impedance bandwidth.

Proposed antenna (Fig.1b) acts in similar way as typical structure. Main bottom patch and parasitic top patch are coupled and form two resonances in VSWR. The presence of two more parasitic elements - microstrip dipoles - leads to excitation of third (high frequency) resonance. This modification allows additional improvement of antenna bandwidth.

### III. ANTENNA ANALYSIS

Initial design and tuning of the investigated antennas is done through the use of software based on Finite Element Method – Ansoft HFSS. This is precise electromagnetic simulator widely used for modeling of different microwave structures. Experimental verification of simulation results is conducted afterwards in order to evaluate real antenna behavior. Photographs of top and bottom radiating elements etched on dielectric substrates for Antenna 1 and Antenna 2 are shown in Fig.2

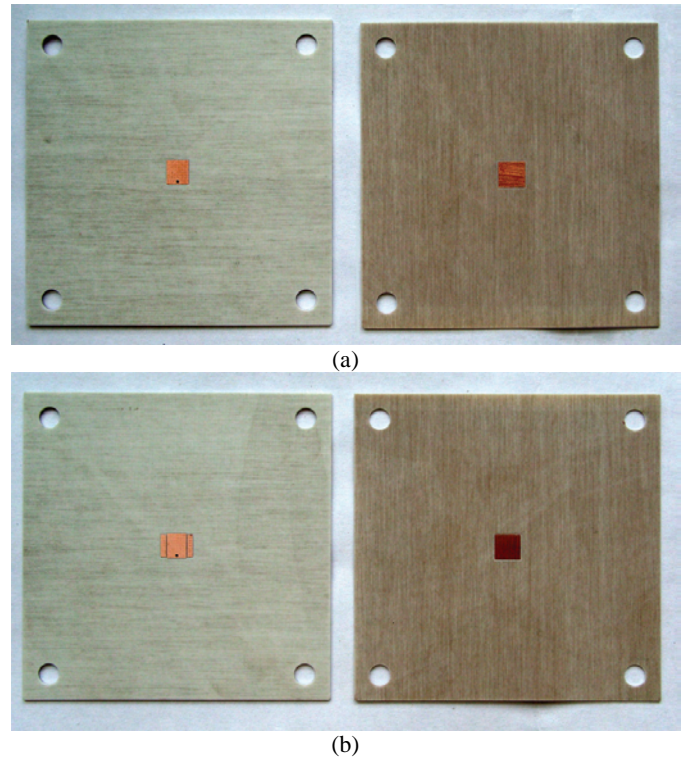


Fig. 2. Test samples of investigated antennas:  
(a) Antenna 1; (b) Antenna 2

Experimental measurements of two antennas are conducted in laboratory conditions. S-parameters are measured with network analyzer N5230A from Agilent Technologies. Fig.3 shows S-parameters measurement setup – assembled antenna connected to the network analyzer.

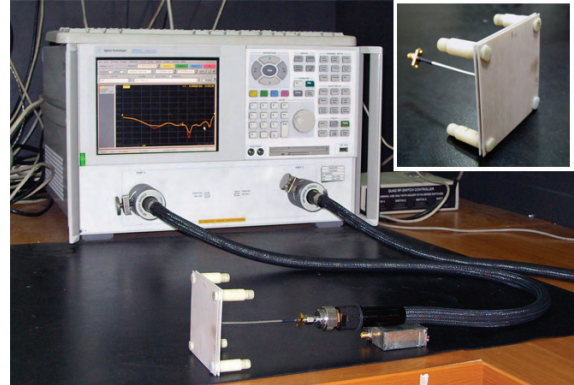


Fig. 3. S-parameters measurement setup

Results for return loss  $S_{11}$  measured for Antenna 1 and Antenna 2 are shown in Fig.4a and 4b respectively. Two types of results are presented in one coordinate system – HFSS simulation (thin line) and measurement (thick line). This allows direct evaluation for the accuracy of software simulations. Very good match between the two types of data is observed concerning frequency bandwidths and return loss values.

Fig.4 clearly shows the advantage of proposed antenna (Antenna 2) compared to typical stacked microstrip element (Antenna 1). In ideal situation (HFSS results) Antenna 1 has only two resonances in return loss:  $f_1=12,9\text{GHz}$  and

$f_2=15,6\text{GHz}$ . Antenna 2 exhibits three clear resonances:  $f_1=13,1\text{GHz}$ ,  $f_2=15,45\text{GHz}$  and  $f_3=16,4\text{GHz}$ . Therefore bandwidth improvement in Antenna 2 is caused by the excitation of the third high frequency resonance ( $f_3=16,4\text{GHz}$ ). As mentioned above this resonance is due to the presence of additional parasitic dipoles adjacent to the main bottom patch.

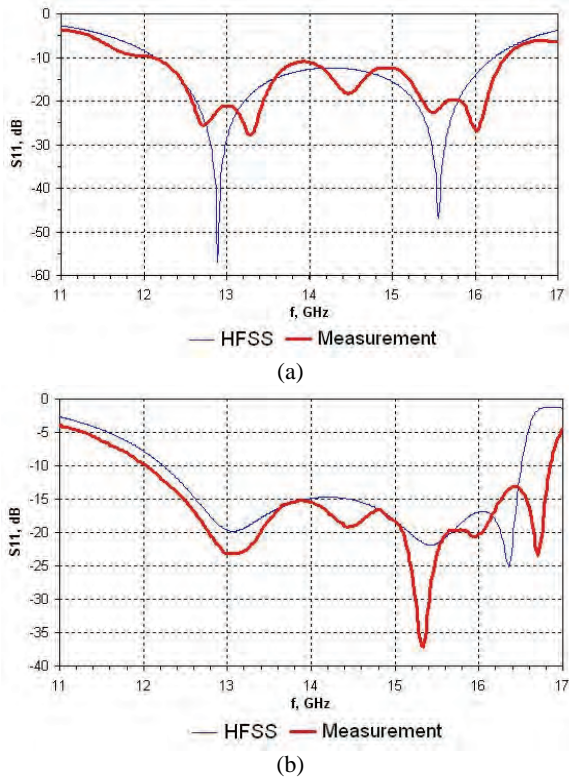


Fig. 4. Simulated and measured return loss: (a) Antenna 1; (b) Antenna 2

TABLE II  
IMPEDANCE BANDWIDTH OF INVESTIGATED ANTENNAS

		Variant	Antenna 1	Antenna 2
BW	$f_L \div f_H$	HFSS	12,17÷16,25	12,3÷16,51
		Measurement	12,17÷16,4	12,05÷16,85
	%	HFSS	28,7	29,2
		Measurement	29,6	33,2

Table 2 contains simulated and measured impedance bandwidths of Antenna 1 and Antenna 2. There is slight difference between simulated and measured value of bandwidth for Antenna 2. It is probably caused by very small geometrical dimensions of the test sample and the production tolerances. This is the reason for the shift in frequency of third resonance – measured resonance is 450 MHz higher than simulated. Antenna 2 has another advantage compared to Antenna 1 except wider bandwidth. Impedance matching for the middle region of the working band is much better for Antenna 2. For frequencies around  $f=14\text{ GHz}$  Antenna 2 has

return loss  $S_{11} \leq -15,4\text{dB}$ , while for Antenna 1 it is fulfilled  $S_{11} \leq -11\text{dB}$ . This means that if we assume  $S_{11} \leq -10\text{dB}$  as limiting condition Antenna 2 has more potential for bandwidth enhancement than demonstrated here.

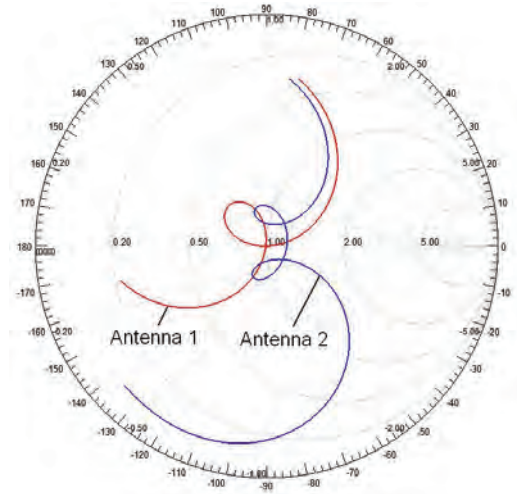


Fig. 5. Input impedance of Antenna 1 and Antenna 2

Fig. 5 shows input impedance of Antenna 1 and Antenna 2 plotted on Smith chart. As seen Antenna 1 has one loop near the center of the chart. It corresponds to the two resonances in the return loss characteristic. This impedance behavior is typical for two resonance system such as stacked microstrip element. On the other hand Antenna 2 has two loops in Smith chart. Such shape of input impedance corresponds to three resonances in frequency characteristic of the radiating element. Antenna 2 has three resonant elements in its construction. Main bottom patch and top parasitic patch determine low frequency loop in input impedance. Microstrip parasitic dipoles on bottom substrate excite third resonance and therefore determine higher frequency loop in Smith chart.

Radiation properties of investigated structures are evaluated through measurement of antenna gain in anechoic chamber. Fig.6 is a photograph of measured antenna mounted on a positioner in anechoic chamber. Antenna under test is fitted in specially designed measurement box (black square object in photograph), which is covered with absorber for elimination of unwanted reflections.

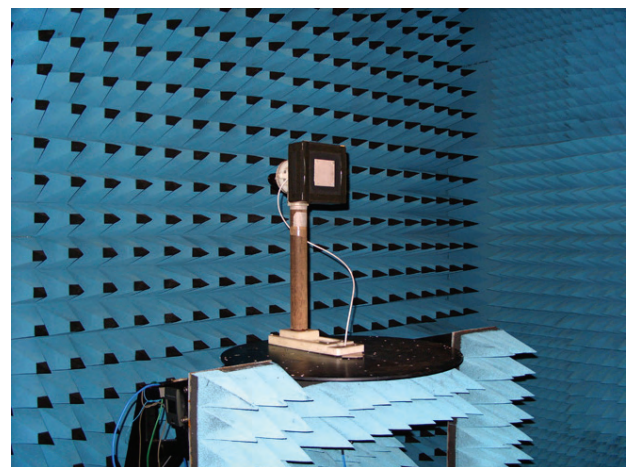


Fig. 6. Measurement in anechoic chamber

Measured gain for Antenna 1 and Antenna 2 is presented in Fig.7. Measured and approximating curves for the gain are plotted on the graph in order to precisely evaluate antenna operation. Results give very close values of gain for the two antennas. This is normal, because constructions of Antenna 1 and Antenna 2 are very similar. It is interesting to note that Antenna 1 has slightly higher maximum gain ( $G_{\max}=8,3\text{dB}$ ) but it drops much quicker at higher frequencies. Antenna 2 has lower gain ( $G_{\max}=8,1\text{dB}$ ) but it is more stable with frequency, which determines wider gain bandwidth of this radiator. Gain bandwidth is defined as the frequency region at the edges of which gain drops with 1dB from its maximum value. Table 3 presents gain bandwidths for Antenna 1 and Antenna 2.

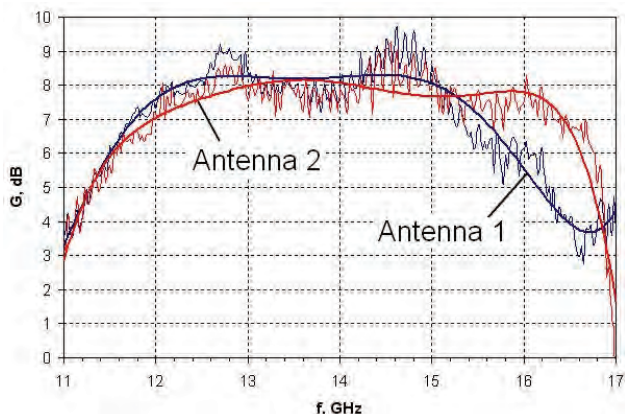


Fig. 7. Gain vs. frequency for Antenna 1 and Antenna 2

TABLE III

GAIN BANDWIDTH OF INVESTIGATED ANTENNAS

Variant		Antenna 1	Antenna 2
BW	$f_L \div f_H$	11,8÷15,5	12,1÷16,4
	%	27,3	30,2

#### IV. CONCLUSION

This paper presents new variant of stacked microstrip antenna, which exhibits improved impedance bandwidth compared to typical antenna of this type. The idea to combine vertically and horizontally positioned parasitic elements presented in [6] is further developed here. As a result alternative three resonance antenna is designed. It differs from typical stacked antenna by the addition of two parasitic microstrip dipoles positioned on both sides of main bottom patch.

Numerical and experimental investigations of proposed and typical antenna are conducted. As a result impedance bandwidth of proposed antenna is  $BW=33,2\%$  compared to  $BW=29,6\%$  for typical construction. This is not very big difference but it must be noted that Antenna 2 (proposed) has much better input match ( $S_{11} \leq -15\text{dB}$ ) than the typical element - Antenna 1 ( $S_{11} \leq -11\text{dB}$ ). The new radiating element has also wider gain bandwidth –  $30,2\%$  compared to  $27,3\%$  for typical antenna.

It should be noted that proposed antenna preserves all advantages of typical stacked patch – it has symmetrical construction which determines symmetrical and stable radiation pattern in working band; small physical area of the antenna (there is just slight enlargement of the size in proposed element); small size makes the radiator suitable for array applications; etc.

Presented three resonance stacked element radiates one sense of linear polarization. Modern communications systems often demand operation with different types of polarization – RHCP and LHCP, two orthogonal linear polarizations. Therefore one potential goal for future work of the author is development of similar antenna, which can radiate different types of polarization.

#### REFERENCES

- [1] R. Garg, P. Bhartia, I. Bahl, and A. Ittipiboon, *Microstrip Antenna Design Handbook*, Norwood, Artech House, 2001
- [2] R. Garg, and V. S. Reddy, "A Broad-Band Coupled-Strips Microstrip Antenna", *IEEE Trans. Antennas Propagat.*, vol. 49, pp. 1344–1345, 2001.
- [3] G. Kumar and K. C. Gupta, "Broad-Band Microstrip Antennas Using Additional Resonators Gap-Coupled to the Radiating Edges," *IEEE Trans. Antennas Propagat.*, vol. 32, pp. 1375–1379, 1984.
- [4] F. Croq and D. M. Pozar, "Millimeter Wave Design of Wide-Band Aperture-Coupled Stacked Microstrip Antennas," *IEEE Trans. Antennas Propagat.*, vol. 39, pp. 1770–1776, 1991.
- [5] S. D. Targonski, R. B. Waterhouse, and D. M. Pozar, "Design of Wide-Band Aperture-Stacked Patch Microstrip Antennas," *IEEE Trans. Antennas Propagat.*, vol. 46, pp. 1245–1251, 1998.
- [6] S. R. Baev, and N. I. Dodov, "Bandwidth improvement of an aperture-coupled stacked microstrip antenna", *Proc. ICEST 2006*, June 29–July 1, Sofia, Bulgaria, pp. 21–24, 2006.
- [7] S. R. Baev, and N. I. Dodov, "Investigation of a stacked microstrip antenna with wide impedance bandwidth", *Telekom 2006*, October 12–13, Varna, Bulgaria, pp. 294–299, 2006.