LOW COST BROADBAND CIRCULAR PATCH MICROSTRIP ANTENNA USING IDMA CONFIGURATION

Dushyant Singh[1], P. K. Singhal[2] and Rakesh Singhai[3]
[1]Asst. Professor, Dept. of Electronics & Comm. Engg. , FET RBS College, Agra, India
[2]Professor, Dept. of Electronics, MITS, Gwalior, India
[3]Professor, Dept. of Electronics & Comm. Engg. , UIT, RGPV, Bhopal, India

ABSTRACT

Antenna is an important component of communication systems. Microstrip antenna find use in a number of application due to its features such as light weight, small size, easy to mass produce etc. But a very serious limitation of microstrip is its low bandwidth typically in the range of 1-2%. This paper investigates experimentally an alternative approach in the bandwidth enhancement of microstrip antenna. The antenna is designed to operate at a resonant frequency of 1.5 GHz with glass epoxy used as dielectric material. The return loss and radiation characteristics of the proposed microstrip antenna are compared with the reference antenna radiation characteristics, which is a conventional circular patch antenna. The configuration used for enhancing the bandwidth of microstrip antenna is Identical Dual Patch with Air gap. In this configuration bandwidth enhancement is achieved by vertically stacking an identical circular shaped parasitic element. The spacing between the driven patch and the parasitic element 'h' is optimized to maximize electromagnetic coupling between the two, which results in enhancement of the bandwidth.

KEYWORDS: *Parasitic element, IDMA, Bandwidth enhancement*

I. INTRODUCTION

The bandwidth of a microstrip antenna [3], [4], [5] can be enhanced by modifying the shape of the patch, by implementing multiresonator configuration, or by using multilayer configuration [6]. The same can also be achieved by using stacked mutiresonator method or by using impedance matching networks [7]. Bandwidth enhancement for Patch Antenna Using Stacked Patch and Slot has been reported recently [9].

This paper investigates a technique which can enhance the bandwidth of the microstrip antenna without increasing the lateral size and the structural complexity of the microstrip antenna too much. The Identical Dual Patch Microstrip Antenna with Air-Gap (IDMA) [1], [2] as shown in fig. 1 takes the advantage of using the air gap to lower the effective permittivity and increase the total thickness of the microstrip antenna which is essential for bandwidth enhancement [8,11].

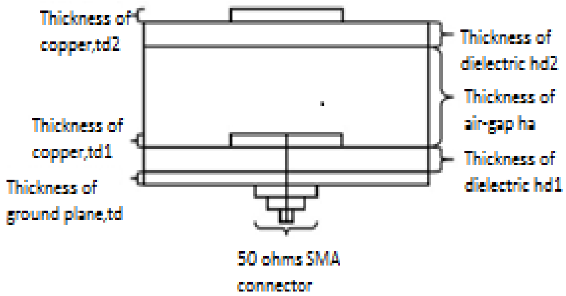

Figure 1. Structure of the IDMA configuration

Section I discuss the introduction to bandwidth enhancement of microstrip antenna and IDMA configuration. In section II of the paper, the methods used for analysing and designing of the antenna using IDMA configuration are discussed. Section III discusses the simulation results and the experimentally obtained results of the reference antenna. The IV section explains the IDMA configuration and discusses the simulation and experimental results for the same.

II. METHODOLOGY

We begin the design process of Identical Dual Patch Microstrip Antenna by designing a reference antenna based on the cavity model approach and using IE3D software for the simulation. Considering the result of the reference antenna as basis we try to increase the bandwidth of the antenna using IDMA configuration. Finally we compare the results obtained for the IDMA configuration with the results of the reference antenna. We use the cavity model approach for the analysis.

2.1. The Cavity Model

In the cavity model approach [8], the region between the patch and the ground plane is treated as a cavity that is surrounded by magnetic walls around the periphery and by electric walls from top and bottom. The field under the patch is expressed as a summation of the various resonant modes of two dimensional resonators. The fringing effect is compensated by extending the patch boundary outward, so that, the effective dimensions are larger than the physical dimension of the patch. As per the cavity model approach the radius 'a' of the circular patch is given by equation (1).

$$a = \frac{F}{\left\{1 + \frac{2h_t}{\pi \varepsilon_{av} F}\left[\ln\left(\frac{\pi F}{2h_t}\right) + 1.7726\right]\right\}^{\frac{1}{2}}} \quad (1)$$

Where

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\varepsilon_{av}}} \quad (2)$$

$$h_t = h_{d_1} + h_a + h_{d_2} \quad (3)$$

$$\varepsilon_{av} = \frac{\varepsilon_1 h_{d_1} + \varepsilon_2 h_a + \varepsilon_3 h_{d_2}}{\frac{h_t}{a}} \quad (4)$$

h_{d_1} = Height of lower dielectric substrate plate

h_a = Height of air gap

h_{d_2} = Height of upper dielectric substrate plate

ε_1 = Dielectric constant of upper dielectric plate

ε_2 = Dielectric constant of air gap

ε_3 = Dielectric constant of lower dielectric plate

ε_{av} = Average dielectric constant

h_t = Total height of antenna

f_r = Resonant frequency

a = Radius of circular patch

Substituting ε_2=1, ε_3=ε_1=4.2, f_r=1.5 GHz, h_1=1.6 mm, h_a=2 cm, h_3=1.6 mm in equation (1), (2), (3) and (4), we get the radius a=28.2 mm for the reference antenna and a=24.7 mm for the radiating patch of IDMA configuration.

III. REFERENCE ANTENNA AND RESULTS

The simulation results of reference antenna are shown in the fig. 3, fig. 4, fig. 5 and fig. 8, and based on these results, we find that the return loss is minimum when the feed point coordinates are (x = 0, y = -11.5) and the value of the return loss is -26.07dB as shown in fig. 3. The fig. 2 shows the prototype of the reference antenna, designed with feedpoints at the above mentioned coordinates.

The VSWR graph is shown in fig. 4. The value of VSWR is 1.1047. The smith chart, current distribution and radiation pattern of the reference antenna are shown in fig. 5, fig. 6 and fig. 7 respectively.

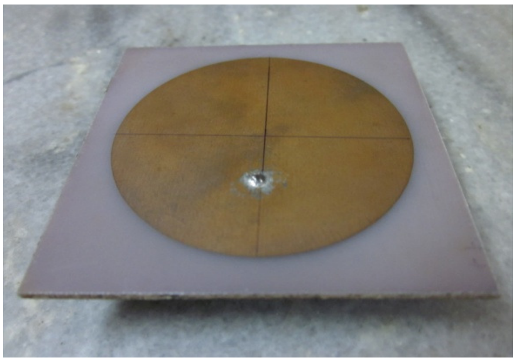

Figure 2. Reference antenna

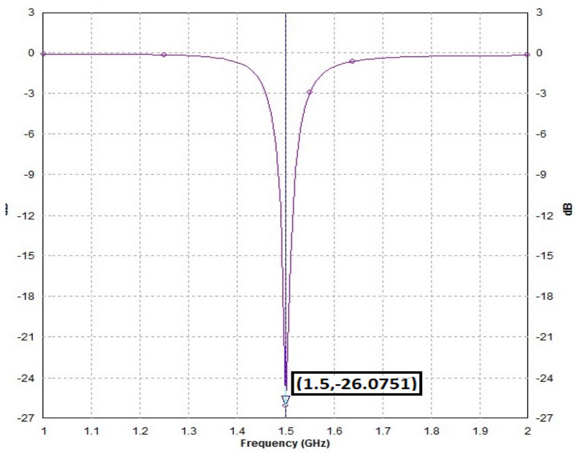

Figure 3. Return loss graph for reference antenna

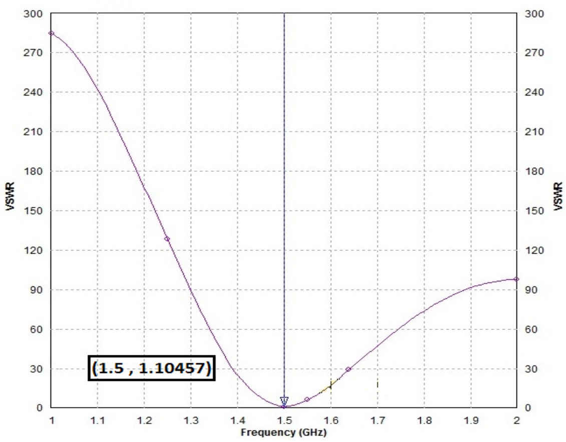

Figure 4. VSWR graph for reference antenna

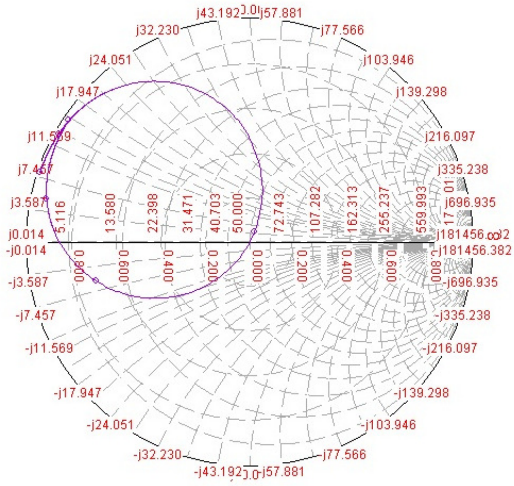

Figure 5. Smith chart for reference antenna

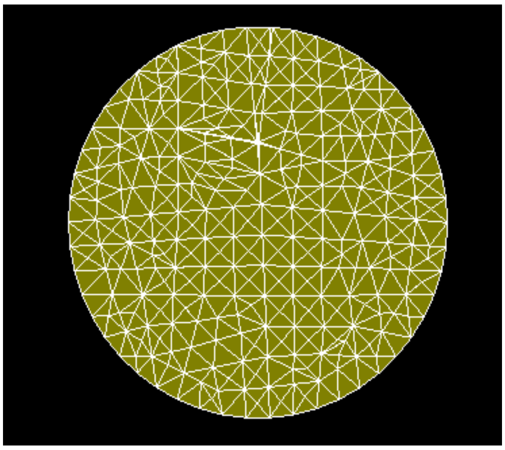

Figure 6. Current distribution for reference antenna

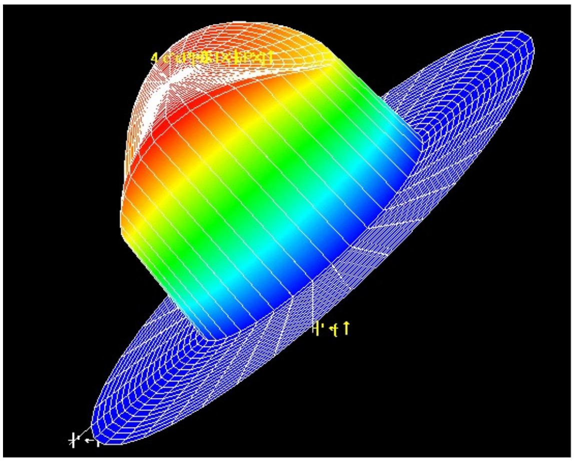

Figure 7. Radition pattern for reference antenna

The reference antenna is tested using spectrum analyzer. The return loss values obtained by testing the reference antenna are shown in the fig. 8.

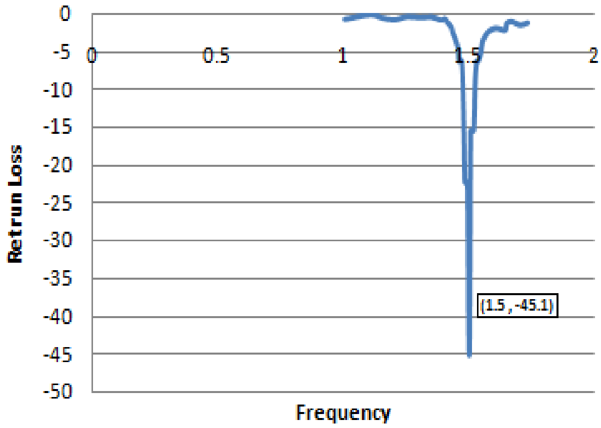

Figure 8. Graph for practical value of return loss

The bandwidth of the reference antenna is calculated as follows:

$$\text{Bandwidth} = f_2 - f_1 \quad (5)$$
$$= 1.518\text{-}1.476 \text{ GHz}$$
$$= 42 \text{ MHz}$$

$$f_{avg} = \frac{f_1 + f_2}{2} = 1.497 \text{ GHz} \quad (6)$$

$$\text{Bandwidth } \% = \frac{f_2 - f_1}{f_{avg}} \times 100 = 2.8\% \quad (7)$$

Here f_1 and f_2 are the lower and the upper cut off frequencies and can be obtained from the return loss graph, and f_{avg} is the average value of f_1 and f_2 .

IV. IDMA CONFIGURATION AND RESULTS

The radiation bandwidth of a microstrip antenna can be enhanced by using aperture stacking [12]. In the IDMA configuration a parasitic element of identical shape is vertically stacked on the driven patch. In this design, height of dielectric plate is taken 1.6 mm and the height of air gap is optimized to 20 mm by performing a number of simulations with different heights of the air gap. The radius calculated using equation 1 is 'a' = 24.7mm. This configuration is simulated using IE3D software at the resonant frequency of 1.7 GHz. We find that the minimum return loss is obtained at this frequency at feedpoints x = 14.245mm, y = 0.175mm. As shown in the fig. 10, at resonant frequency of 1.71GHz the return loss is equal to -22.5dB and the value of VSWR is shown in fig. 11.

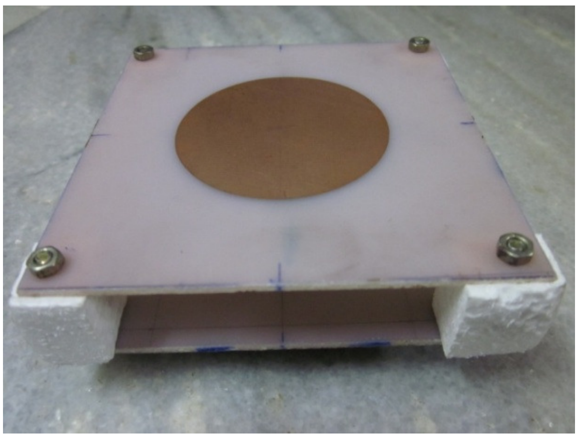

Figure 9. IDMA configuration

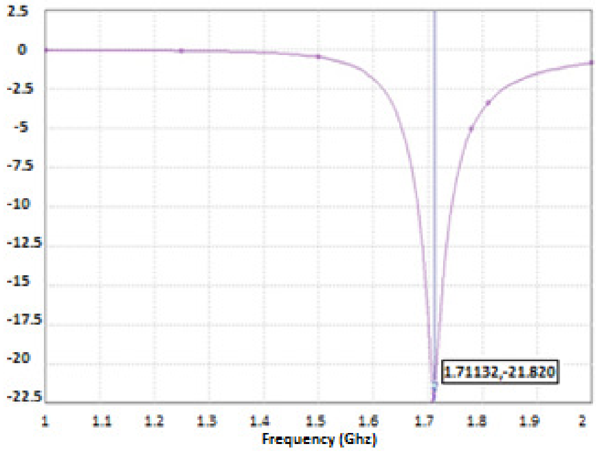

Figure 10. Return loss curve for IDMA config.

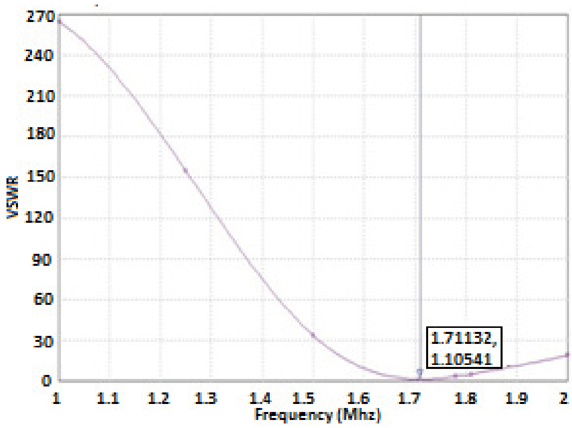

Figure 11. VSWR graph for IDMA config.

The smith chart, current distribution & radiation pattern for the IDMA configuration are shown in the fig. 12, fig. 13 & fig. 14 respectively.

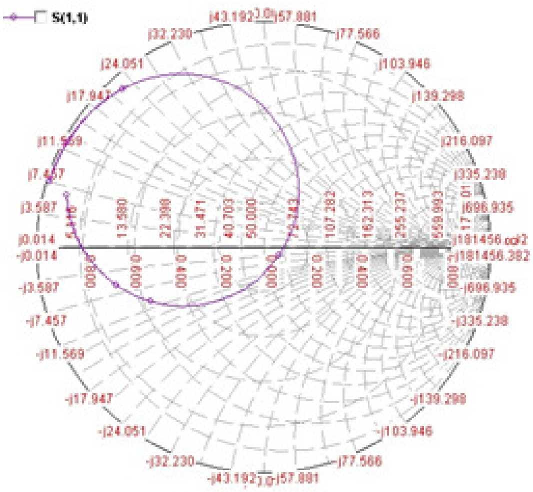

Figure 12. Smith chart for IDMA config.

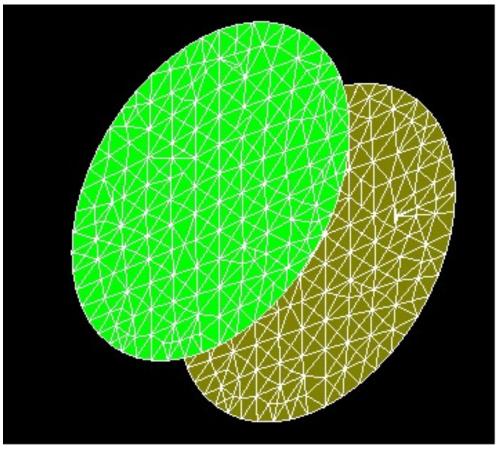

Figure 13. Current distribution for IDMA config.

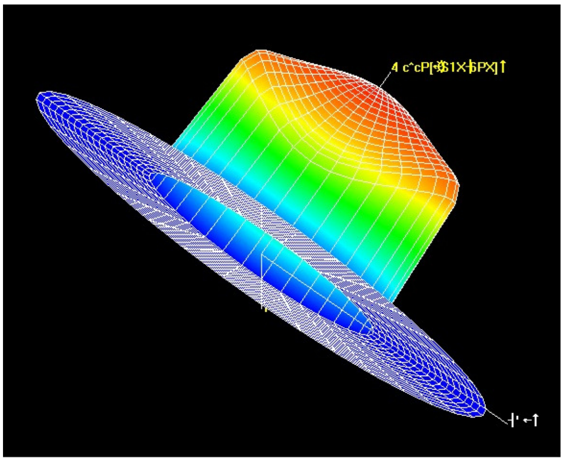

Figure 14. Radiation pattern of IDMA config.

The return loss graph for the IDMA configuration is shown in fig. 15.

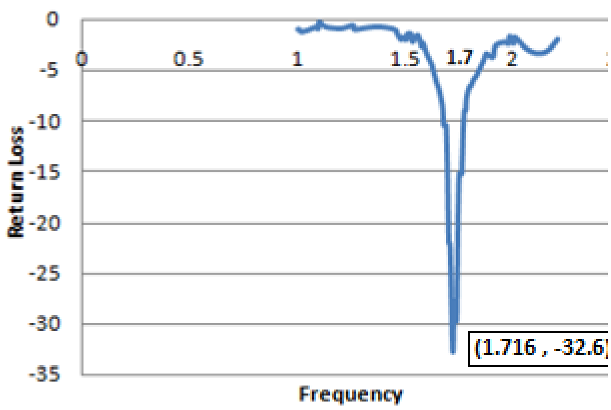

Figure 15. Practical value of return loss for IDMA configuration.

The bandwidth of IDMA configuration is calculated as follows:-

$$\text{Bandwidth} = f_2 - f_1 \quad (8)$$

$$= 1.764\text{-}1.674 \text{ GHz}$$

$$= 90 \text{ MHz}$$

$$f_{avg} = \frac{f_1 + f_2}{2} = 1.719 \text{ GHz} \quad (9)$$

$$\text{Bandwidth } \% = \frac{f_2 - f_1}{f_{avg}} \times 100 = 5.2 \ \% \quad (10)$$

Table 1 shows the comparison between the simulated and measured results of the reference microstrip antenna and identical dual patch microstrip antenna.

Table 1. Comparison between reference antenna & IDMA configuration.

Parameters	**Single –layer Microstrip antenna**		**IDMA**	
	Simulated	**measured**	**simulated**	**measured**
Operating frequency (GHz)	1.5 GHz	1.5 GHz	1.71 GHz	1.71GHz
Radius ‘a’(mm)	28.2 mm	28.2 mm	24.7 mm	24.7 mm
Bandwidth (MHz)	30 MHz	42 MHz	61 MHz	90 MHz
Return loss (dB)	-26.07	-45.1	-21.82	-32.6

The return loss of the reference antenna, which is a single layer microstrip antenna is -45.1dB at a resonant frequency of 1.5GHz & with a bandwidth of 42 MHz. On the other hand the return loss of the IDMA configuration is -32.6dB at a resonant frequency of 1.71 GHz & with a bandwidth of 90MHz. Hence by using IDMA configuration the bandwidth of the antenna is enhanced, but at a higher resonant frequency & with a reduced return loss.

V. CONCLUSIONS AND FUTURE PROSPECTS

The experimental results obtained for the reference antenna show that the value of return loss is -45.1 dB with a bandwidth of 42 MHz at a resonant frequency of 1.5 GHz whereas the experimental results for the IDMA configuration show that return loss is -32.6 dB with a bandwidth of 90MHz at a resonant frequency of 1.71 GHz. The results show that the circular antenna designed using IDMA technique becomes broadband at 1.71 GHz. This technique has its advantages such as it does not increase the lateral size of the microstrip antenna and disadvantages such as it increases the height of the microstrip antenna and the resonant frequency changes from 1.5 GHz to 1.71 GHz. Therefore, trade of issues need to be considered in this design.

As future prospects, the bandwidth can further be improved by using metamaterial substrate in the IDMA configuration [10] or by replacing the circular patch on the upper layer by a patch of other shape and then optimizing the gap between the two layers.

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AUTHORS

Dushyant Singh was born in Agra, India in the year 1981 and he is currently working as Asst. Professor in department of Electronics & Communication Engg., Raja Balwant Singh Engineering Technical Campus, Bichpuri, Agra. He completed his B.E from Dr. B R Ambedkar University Agra & M.Tech from Gautam Buddh Technical University, Lucknow. His area of interest is Microstrip Antennas and his specialisation is in VLSI design . He has also worked on projects based on genetic algorithm & he has published several paper in national and international conferences and journals.

Pramod Kumar Singhal was born in the year 1965. He received his B.E degree in Electonics Engg. form Jiwaji University, Gwalior in 1987, M.Tech degree in Microwave Electronics from University of Delhi, Delhi in 1989 and Ph.d degree in Electronics Engg. from Jiwaji University, Gwalior in 1997. He has an experience of teaching, research and development of over 20 years and presently working as Professor and Head of Department of Electronics, MITS, Gwalior. He has guided 6 Ph.Ds, more than 100 M.E/M.Tech and several B.E/B.Tech projects. He has more than 100 papers in National/International conferences and Journals to his credit. His area of interest are Microwave Engg., Communication system, Microwave antennas and Computer aided design of microwave integrated circuits. He is a life member of ISTE, Delhi, Insitute of Engineers, Calcutta, Computer society of India, Mumbai.

Rakesh Singhai received B.E. degree in Electronics and Telecommunication Engineering from Government Engineering College, Jabalpur, MP, India in 1987 and M. Tech. degree in Communication and Radar Engineering from Indian Institute of Technology Delhi, New Delhi, India in 1995. Dr Singhai obtained his Ph.D. degree from Electrical Engineering Department, Indian Institute of Technology Delhi in the area of Network Traffic Modeling. He was a Lecturer in the Government Engineering College, Bhopal, India from 1989, and, after the merger of college with the Rajiv Gandhi Technical University, he became faculty in University Institute of Technology, Rajiv Gandhi Technical University, Bhopal, MP, India where he is a Associate Professor and Head of Electronics & Communication Engineering Department. His area of interest includes Computer Network, Signal Modeling, Queuing Theory and Signal Processing. He is a fellow of Institute of Electronics & Telecommunication Engineers (IETE), New Delhi, India, and a life member of Indian Society for Technical Education (ISTE), New Delhi, India. Dr. Singhai received the Best Student Paper Award in 15th International Conference on Software, Telecommunications and Computer Network (SoftCOM 2007), Split-Dubrovnik, Croatia, Sept. 27-29, 2007.