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# New Thoughts And Innovations For Wider Applications Of Microstrip And Dielectric Resonator Antennas

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**Abstract** This article addresses major technical contributions started and done initially by me, and later on in collaboration with my students and associates. All the works are in the field of microwave and wireless antennas, which include both microstrip and dielectric resonators. Only those works, which show considerable impact on antenna community and industry, have been considered in here for discussion.

**Keywords**: Microstrip antenna, dielectric resonator antenna.

## 1. INTRODUCTION

Primary aim of this article is to focus on my research works, which I started in late 1990s and subsequently pursued with my students and associates and especially those which showed considerable impact on antenna community in a short period of time. All the works included in this article are available in open literature, published during the period of 2001-2012. They include both microstrip and dielectric resonator antennas for microwave and wireless applications.

For microwave frequencies, only aperture type antennas were known until 'microstrip antenna' was realized in early 1970s [Howell (1972)]. 'Microstrip' is very similar to 'printed circuit board' or PCB, which uses low-loss thin dielectric wafer, sandwiched between two thin layers of copper. Microstrip antenna grew over last four decades and has become inevitable part of modern civilization. If we now decide to withdraw 'microstrip antenna' from every sphere of its application, within a moment it will create the crisis of survival without having any telephone, cell phone, internet; GPS service; radar and navigational aids; civil aviation; object identification; defence and security, and also advanced medical support.

In 1990's, the concept of integrated antenna grew rapidly and those used microstrip as basic antenna element. Late 1990s was the time when I entered into the antenna field and picked up microstrip for doing research, especially with a view to explore multi-layered microstrip structures for advanced design. This ultimately led to establishing advanced design concepts, which are now commonly used by others, and some of which have been adopted in famous text book by J D Kraus and others [Kraus et al. (2010)]. Those works are discussed in Section-2.

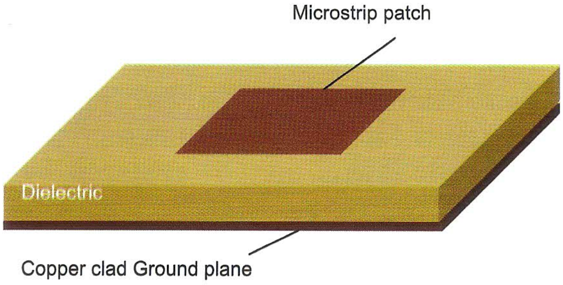

**Figure 1: Conventional geometry of microstrip patch**

In a microstrip circuit or antenna, the electromagnetic fields are confined within the

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conductors on the top (look like a 'strip' for a circuit or a 'patch' for an antenna) and a ground plane at the bottom as shown in Fig. 1. Around 2001-2002, a group of circuit engineers introduced small 'defects' in the ground plane of microstrip circuits to achieve an interesting features in the propagating waves. The 'defect', in here, means small etched out area in the ground plane. So far, 'microstrip antenna' was virgin in terms of its ground plane configuration. In 2005-2006, we first tried to modify the radiation from a microstrip antenna employing shaped defects in the ground plane. Those indeed opened up a new avenue of research, which resulted in tremendous development in microstrip technology in last 7-8 years. Several antenna groups in leading laboratories including the National Center for Atmospheric Research (NCAR) at Boulder are involved in such development for new generation Radars. Our specific contributions in this field are discussed in Section 3.

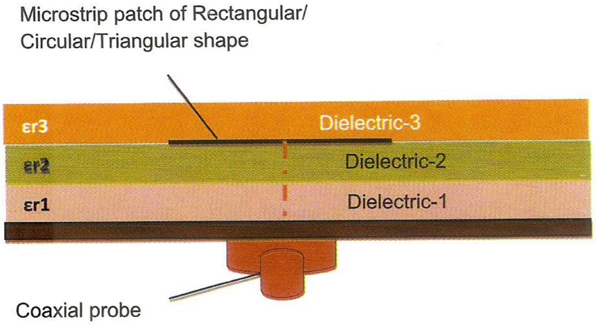
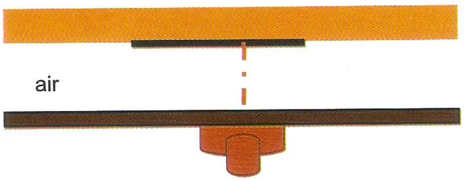


**Figure 2: Multi-layered substrate/ superstrate combinations for microstrip antenna. Any of the dielectric layers may be replaced by air (εr=1).**

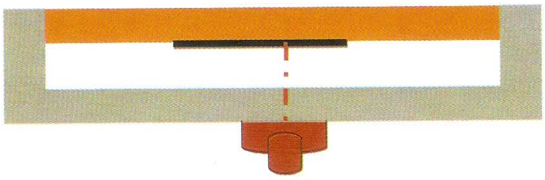
In antenna engineering, after microstrip, the next breakthrough occurred in 1983, when Long and his collaborators [Long et al.(1983)] demonstrated a simple dielectric block (nonmetal substance) as a good radiator. This gave birth to Dielectric Resonator Antenna (DRA), which is expected to be the antenna of the future, especially when we need to integrated all in one chip. By virtue of open boundary, a DRA offers huge scope of playing with its modes, which we first conceived in 2006 and realized several new designs for wideband and Ultrawideband (UWB) operations.

After 30 years of invention, now we can claim the credit of adding a new radiating mode in cylinder shaped DRA, which also has added a new form of feed mechanism, not known to antenna community. We believe that, the DRA researchers will acquire new thoughts from this work to advance the technology to more matured state. Our contributions on different aspects of DRA have been discussed in Section 4.

Three major areas of our contribution have been identified and briefly discussed in subsequent sections.



Inverted circular microstrip



cylindrical cavity-backed

**Figure 3: Inverted microstrip – open and cavity backed configurations.**

## 2. COMPOSITE SUBSTRATE / SUPERSTRATE BASED MICROSTRIP ANTENNA DESIGN

Conventional microstrip antenna uses single uniform dielectric layer, which holds the radiating patch on its upper surface as shown in Fig. 1. The bottom surface is copper clad serving as the ground plane.

Our approach was to analyze a generalized configuration, shown in Fig. 2, which allows one to choose any combination as per the requirement. We had separately dealt circular, rectangular and triangular shapes of microstrip patch considering their individual importance and relevance in antenna technology [Guha (2001)], [Guha and Siddiqui (2002), (2003), (2004), (2004)], [Siddiqui and Guha (2003)], [Guha et al. (2005), (2007)], [Guha and Antar (2006)], [Biswas et al. (2006)], [Chattopadhyay et al. (2009), (2009), (2009)].

Primary significance of our works was to obtain an authentic computer aided design (CAD) to alleviate existing lapse of information. This is revealed from their frequent use by other researchers and citations in almost all the subsequent works reported in open literature. We would specially mention about two important structures, shown in Fig. 3, which find potential applications in accommodating active devices beneath the patch.

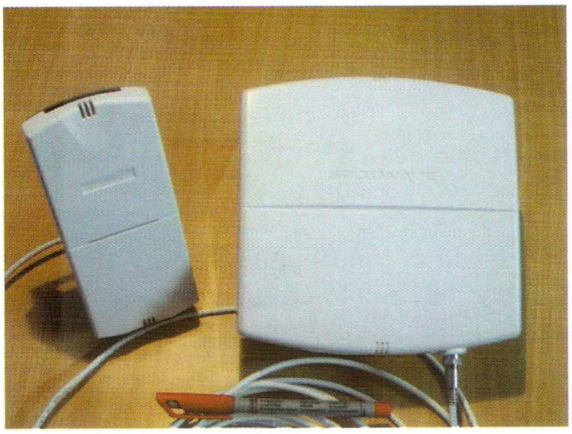


**Figure 4: Photograph of a commercial product showing high gain wireless antenna developed for an industry**

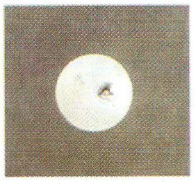
This is one simple way of realizing integrated antennas for various purposes. Before our theoretical formulations reported through [Guha and Siddiqui (2002), (2004)], [Siddiqui and Guha (2003)], the integrated antenna people had to experimentally characterize each and every time.

These technical insight and theoretical background helped us to resolve a challenge for the industry - to double the antenna gain (operating in GSM/PCS band) without compromising with its volume! The intellectual property right of our design was purchased by Spotwave, a North American Wireless Industry, which launched it as a commercial product (Fig. 4) in 2007.

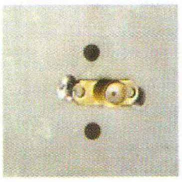
## 3. DEFECTED GROUND STRUCTURE FOR ANTENNA APPLICATIONS

Basic idea about a defect on microstrip ground plane is discussed in Introduction. The term 'Defected Ground Structure' or simply 'DGS' was coined by Kim and others [Kim et al (2000)]. It gradually became popular in printed circuit applications. In 2005, we first introduced a pair of 'dot' shaped DGS beneath a circular patch to suppress unwanted cross-polarized radiations [Guha, Biswas and Antar (2005)]. A photograph of the DGS-integrated antenna is shown in Fig. 5. This was the first application of DGS to modify antenna characteristics. This in turn unveiled an unknown reason behind the mysteries of cross-polarized fields.

In subsequent years, we were able to focus on a very important application of DGS. We first showed how a DGS can be employed to mitigate mutual coupling issue in the arrays of microstrips [Guha, Biswas et al (2006)]

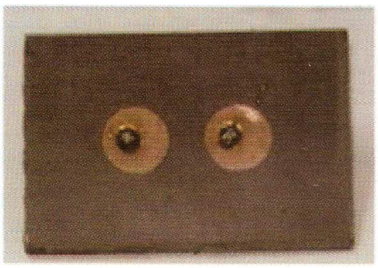


Viewed from top side

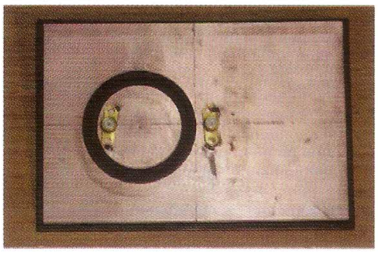


Viewed from bottom side

**Figure 5: First DGS-integrated antenna explored to suppress cross-polarized radiations.**



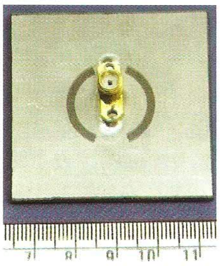
Two element microstrip array



Annular ring DGS surrounding one of the patches

**Figure 6: DGS-integrated antenna array explored to suppress mutual coupling.**

and DRAs [Guha et al (2008)]. We experimented with a simple ring-DGS for two-element array as shown in Fig. 6. These two works ushered a new light to resolve a longstanding issue of arrays by applying DGS. Reduction of scan blindness is one of the most important outcomes of subsequent research by other groups [Hou et al. (2009)]. Related developments up to the late 2010s have been covered in [Guha and Antar (2011)].



Viewed from ground plane side

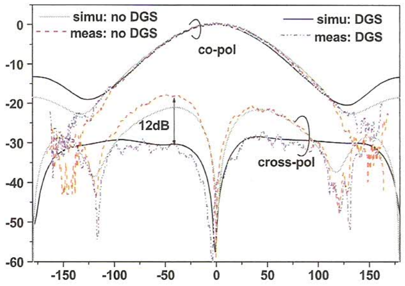


**Figure 7: Arc-shaped DGS suppresses cross-polarized radiations by 127dB in H-plane, Results in C-band.**

In our subsequent works with DGS [Guha, Kumar and Pal (2009)], [Kumar and Guha (2012)], we have addressed advanced DGS geometries along with some fundamental aspects. One of them is shown in Fig. 7, which results up to 12 dB reduction in the unwanted radiations. Two different modes of operation (non-resonant and resonant) have also been identified and established experimentally. We also have explored a different approach of universal design [Kumar and Guha (2012-Chicago)] and sincerely believe that, DGS has already established itself as a very useful tool for advanced antenna design.

## 4. MODE-ENGINEERING FOR ADVANCED DRA DESIGNS

Like any resonant structure, a DRA also suffers from limited operating bandwidth, which is primarily determined by the permittivity of the material and the physical dimensions. The researchers have tried with several techniques to enhance its operating band.

Our specific contribution in this field was in introducing mode-engineering technique to couple multiple resonances in same structure to produce

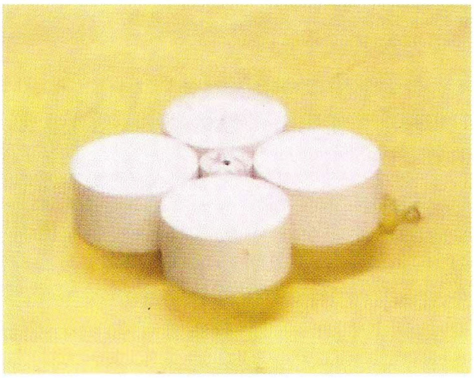


**Figure 8: Four-element composite DRA serving compact (low height) wideband monopole.**

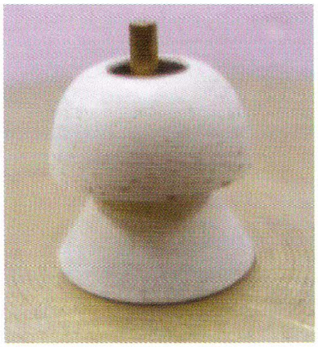


**Figure 9: Pawn shaped dielectric ring surrounding a vertical monopole: a UWB design.**

wideband operation with identical radiation patterns. In doing this, we have explored different compositions and shape. One of them is multi-element configuration, which has been explored in different forms in [Guha and Antar (2006-No.9), (2006-No.12)]. A representative example is shown in Fig. 8. The art of designing is to exploit more than one resonance producing identical radiations, which is impossible to achieve in a single DRA unit. This approach does not require additional volume and as such is advantageous in realizing low loss wireless antenna for miniaturized transceiver systems. This mode-engineering technique has been adopted widely for low-profile DRA design.

Metal-Dielectric hybrid monopole is another field of our investigation. A marriage between an electric monopole and a dielectric ring monopole results in an UWB antenna, which was first experimentally observed by Ittipiboon and his collaborators in [Ittipiboon et al. (2002)]. But designing such antenna for a specified band was a great challenge at that time. To fill up the lacunae, we developed a physical insight into their modal behaviour and proposed a solid design guideline [Guha et al (2006)]. That knowledge indeed caused a flux of investigations all over the world resulting in more than 15 new UWB monopoles within a short period of time. We further have shown that proper shaping of the dielectric ring is a right approach to allow additional resonances resulting in enhanced bandwidth towards higher and higher frequencies [Guha, Gupta and Antar (2009)], [Guha, Gupta et al. (2012)]. Fig. 9 shows one of our complex shaped dielectric rings providing nearly 122% impedance bandwidth covering 5.5 to 23 GHz.

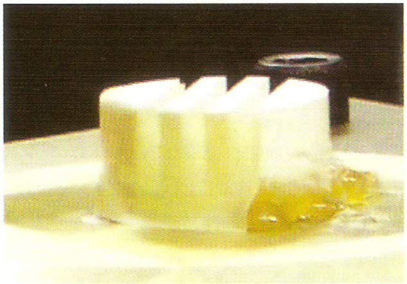


**Figure 10: comb-shaped cylindrical DRA conceived as circularly polarized antenna.**

Strategic shaping of DRA helps in moulding its modal fields, which we explored through our investigations in different forms. We have demonstrated circular polarization just by introducing shaped slot-ridge combination in a cylindrical DRA as shown in Fig. 10 [Chu, Guha and Antar (2007)]. Another example of simple shaping is shown in Fig 11, which serves as a wideband wireless antenna covering four specified wireless services [Chu, Guha and Antar (2009)]. Engineering of such structures is bit critical; but we hope to overcome these shortcomings in the near future with the advent of new generation dielectric materials.

Recently, we have been successful in adding a new radiating mode to DRA family. Normal DRA environment does not support its modal fields. A novel feed mechanism has been introduced and described in [Guha, Banerjee et al (2012)]. This needs further investigations and we believe that the new feed and mode will resolve several issues in the future, one being multiband high gain DRA.

## 5. CONCLUSIONS

All the works, described above, are based on simple innovative ideas, and the concepts were all verified experimentally. For conforming some of the ideas, we had to do extensive experiments

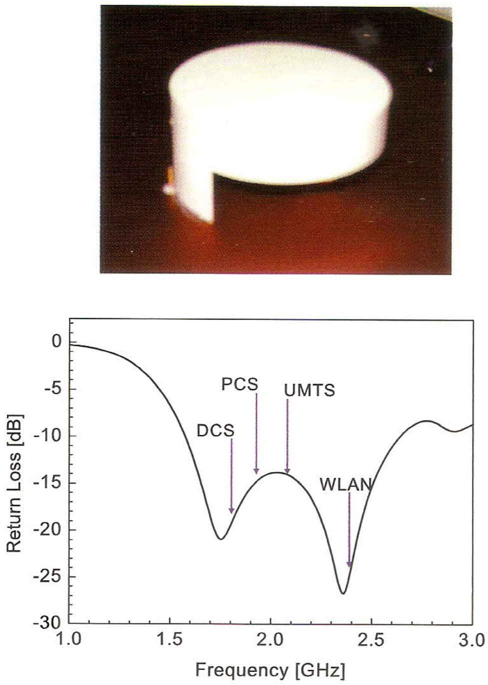


**Figure 11: Shaped DRA serving as wideband broadside radiation antenna covering 4 wireless bands.**

over years and sometimes had to corroborate the design principles by repeating the experiments in different frequency bands. Importantly, most of them were done using limited facilities in Indian laboratory set up.

## Acknowledgement

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