Performance comparison of Micromachined Patch Antenna with EBGs and Soft Structure Substrate

Rakhesh Singh Kshetrimayum, Dipto Dey and S. S. Karthikeyan
Electronics and Communication Engineering
Indian Institute of Technology
Guwahati, India, 781039.
Email: krs@iitg.ernet.in

Abstract:

A comparative study on micromachined patch antenna with electromagnetic bandgap structures (EBGs) and Soft Structure Substrate in terms of its performance viz. antenna bandwidth, antenna directivity and efficiency has been carried out. It has been observed that the former patch antenna configuration gives better directivity whereas the latter patch antenna configuration gives better efficiency. As far as the antenna bandwidth is concerned, both these cases are equally good. All these techniques: micromachining, EBGs, soft structure substrate are techniques for enhancing simple patch antennas performance. We have combined these techniques in this paper and observed that there are improvements in patch antenna performance.

Key Words: Microstrip Patch Antenna, Micromachining, Electromagnetic Band Gap Structures (EBGs), Artificial Soft Structure

I INTRODUCTION:

The most popular method of reducing surface waves and improvement of radiation parameters of a microstrip antenna is the use of electromagnetic band gap structures (EBGs) [1]-[2]. Use of EBGs in the substrate however has the disadvantage that it puts constraint on the substrate size. In order to use EBGs in the substrate a considerable substrate size is required which is not always available. Take for example when antennas have to be designed on small telecommunication gadgets a sector which is so much dictated by the need to size miniaturize existing devices/components, such large substrate dimensions are not always available. The other disadvantage of EBGs is that it is relatively harder to fabricate such structures compared to planar structures.

Papapolymerou et al has investigated that the micromachined antenna can be used to mitigate some of the problems of employing high permittivity substrates [3]. Micromachined antenna increases the bandwidth of the antenna with an increase of antenna dimensions. We had also demonstrated that the use of EBGs and micromachined technologies together on the same substrate enhances the antenna gain and efficiency more than what is achievable by any of the technologies singly [4]-[5]. Micromachining of the antenna substrate stops surface waves generation and EBGs in the substrate stops surface wave propagation. In this section we will use another technology called the soft surface structure [6], which also inhibits the propagation of surface waves. A comparison between the two technologies when used with the micromachined antenna will demonstrate as to which is better in terms of antenna performance.

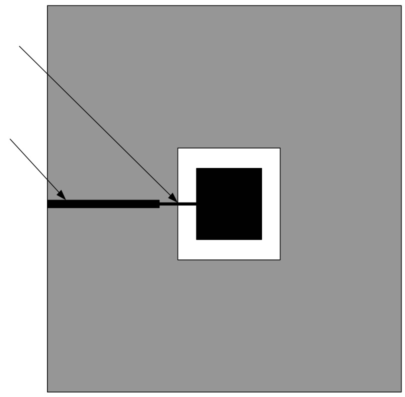

Fig. 1(a)

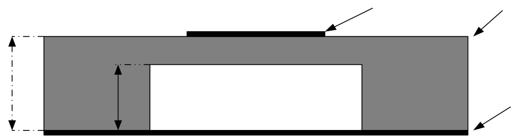

Fig. 1(b)

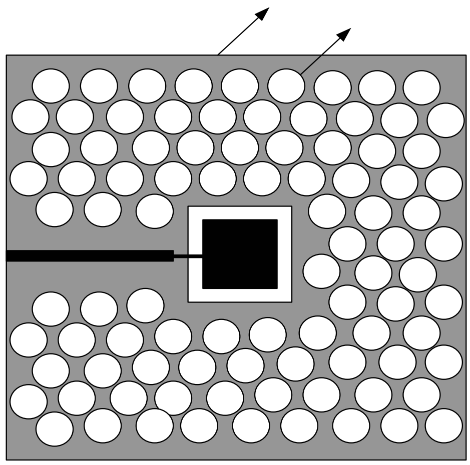

Fig.1(c)

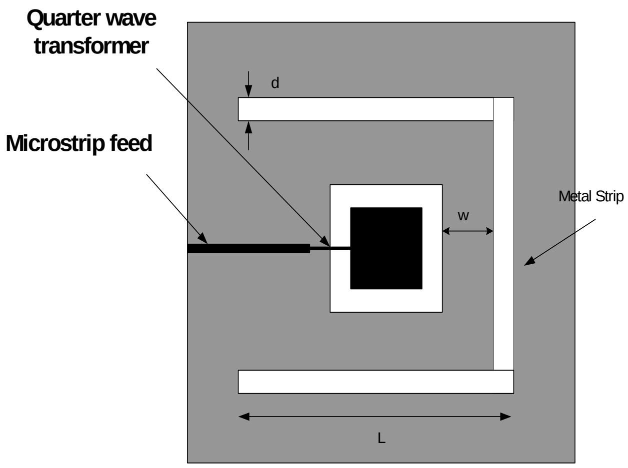

Fig. 1(d)

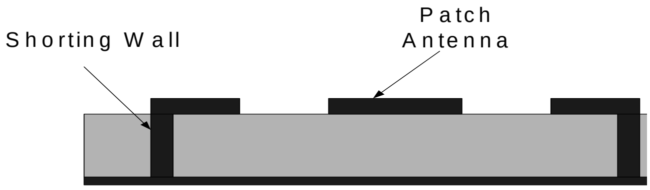

Fig. 1(e)

Figure 1. *Micromachined rectangular patch antenna fed by microstrip line and matching by a quarter wavelength transformer (a) top view showing the feed line and patch (b) side view showing the micromachined structure.* (c) *Front view of EBG assisted micromachined patch antenna (d) Front view of Micromachined patch antenna with soft surface structure and (e) Side view of Micromachined patch antenna with soft surface structure*

II. GEOMETRY OF PATCH ANTENNA WITH DIFFERENT SUBSTRATES

The width and length of the patch antenna shown in Figure 1(a) and (b) were calculated to be 1.969mm and 1.34 mm respectively. The impedance matching is done with the help of inset. The thickness of the microstrip calculated from [7] so as to give a characteristic impedance of 50 ohms at 28 GHz. The thickness of the feed line is thus 0.1978mm. The Gallium Arsenide substrate dimension is 16mm on either side (~1.6λ). The initial set of simulations was carried out so as to design an antenna, which resonates at 28 GHz. All these designs use Gallium Arsenide substrate with thickness of 0.35mm. Note that Gallium Arsenide has a relative permittivity of 12.8. The simulations were carried out using IE3D [8] with the perfect metallic boundary condition applied to the patch and its feed line. The ground was taken as copper with finite conductivity. The micromachined element is made to extend beyond the patch by two times the height of the substrate so as to cover the fringing fields [5]. The height of the micromachined element is taken as 0.25mm with a gap of 0.5mm above and below. A partial square ring for a soft surface substrate surrounds the patch antenna as depicted in Figure 1(b) and (c). In microstrip line fed patch antenna the square ring cannot be put all round the patch but for coaxial fed antenna such a configuration is possible. The ring is shorted to the ground by the help of a shorting wall. This shorted metal strip acts as soft surface structure. The width of the strip is equal to the quarter-guided wavelength. The substrate is Gallium Arsenide with thickness 0.35 mm. The micromachined patch antenna configuration is the same as used for previous design.

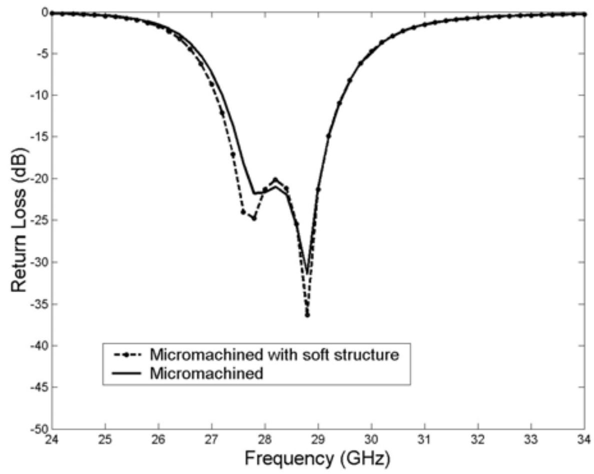

Fig. 2 (a)

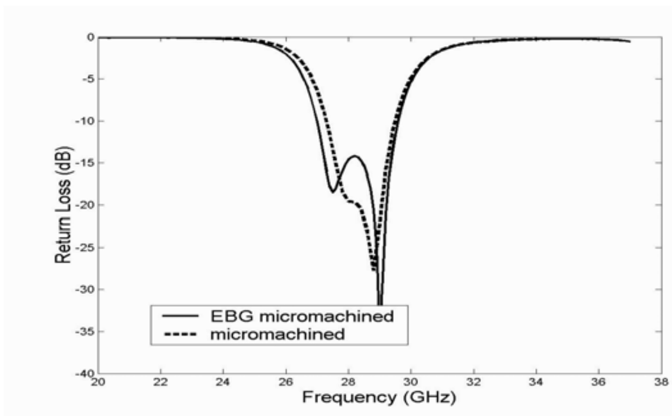

Fig. 2 (b)

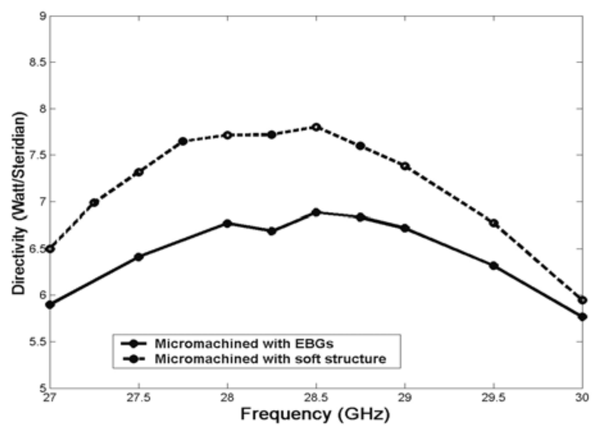

Fig. 2 (c)

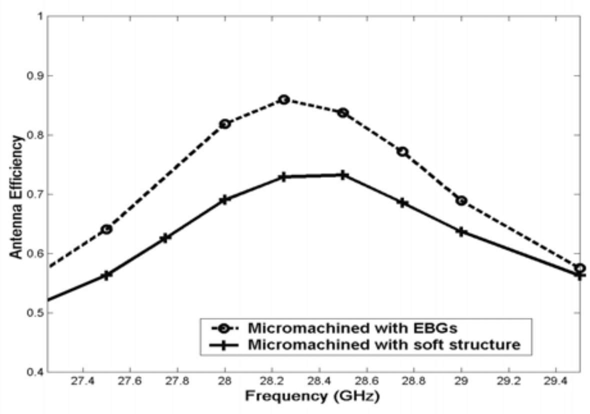

Fig. 2(d)

Figure 2. a) *Return loss of Micromachined and Micromachined Antenna on soft structure substrate* b) *Return Loss in dB micromachined patch and EBG assisted micromachined patch antenna* (c) *Antenna directivity in Watt/Steridian versus frequency for Micromachined antenna with EBGs in substrate and Micromachined antenna with soft structure substrate* d) *Antenna Efficiency versus frequency for Micromachined antenna with EBGs in substrate and Micromachined antenna with soft structure substrate*

III RESULTS AND DISCUSSION

The return loss with inclusion of the soft structure substrate does not show any marked improvement in bandwidth as is expected (refer to Figure 2(a)). Such performance is similar to the results obtained when EBGs was used with the micromachined structure as illustrated in Figure 2(b). As soft structure substrate like EBGs in the substrate does not interfere with the antenna resonance it will not affect the bandwidth.

The comparison of directivity versus frequency is shown for Micromachined antenna with EBGs and Micromachined antenna with soft structure substrate. The directivity for Micromachined antenna with EBGs is less than that of Micromachined antenna with soft structure substrate throughout the 3dB bandwidth (refer to Figure 2(c)). It can be accounted by the fact that the metal strips are located at a distance equal to half the guided wavelength. Thus the metal strips, which have a current distribution on them together with the antenna, form an antenna array. This array configuration is responsible for the better directivity in Micromachined antenna with soft structure substrate. However directivity alone cannot be conclusive as to which antenna has better performance. The applications for which these antennas are intended use high permittivity substrate. The important issue here is the reduction of surface waves. The surface wave effect can be interpreted directly from the antenna efficiency. More the antenna efficiency, less is the dielectric losses, thus less is the excitation of surface waves. Figure 2(d) shows the antenna efficiency versus frequency for Micromachined antenna with soft structure substrate and Micromachined antenna with EBGs. The results show that Micromachined antenna with EBGs is far more efficient than Micromachined antenna with soft structure substrate. Thus for inhibition of surface waves is concerned Micromachined antenna with EBGs is superior. High efficiency antennas should thus use EBGs rather than soft structure substrate.

CONCLUSION

An investigation on comparison of micromachined patch antenna with electromagnetic bandgap structures and Soft Structure Substrate in terms of its performance viz. antenna bandwidth, antenna directivity and efficiency has been carried out. It has been observed that the former patch antenna configuration gives better directivity whereas the latter patch antenna configuration gives better efficiency. As far as the antenna bandwidth is concerned, both these cases are equally good. All these techniques: micromachining, EBGs, soft structure substrate are techniques for enhancing simple patch antennas performance. We have combined these techniques in this paper and observed that there are improvements in various patch antenna performances. Hence depending on specific applications where we require higher directivity and efficiency we can employ one of these combined techniques. Narrow bandwidth is one of the biggest hurdles in the patch antenna for various applications, combined techniques we have discussed above gives a broader bandwidth overcoming this major limitation on the patch antenna performance. Further investigation on such hybrid techniques is an area of future research works.

ACKNOWLEDGMENT

Authors are grateful to staffs at the Systems Simulation Laboratory, IIT-Guwahati for their time and help in carrying out these simulation works.

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BIO DATA

Dr. Rakhesh Singh Kshetrimayum received the B. Tech. degree in Electrical Engineering from the Indian Institute of Technology, Bombay and the Ph.D. degree from the Nanyang Technological University, Singapore. He did his postdoctoral research from the Microwave Lab, Indian Institute of Science, Bangalore and Electromagnetic Communication Lab, Pennsylvania State University, University Park. Since 2005 he is a faculty member at the department of Electronics and Communication Engineering, Indian Institute of Technology, Guwahati and presently he is an Assistant Professor. His research interests include RF, Microwaves, Antennas, Numerical Electromagnetics and Neural Networks.

Dipto Dey received the B. E. degree in Electronics and Communication Engineering from the University of Burdwan in 2005 and M. Tech. degree in Electronics and Communication from the Indian Institute of Technology, Guwahati in May 2007. He won first prize in Motorola Motofwd Scholarship College Competition 2006. His research interests include Electromagnetic Band Gap substrates, Patch Antennas and Micromachining.

S. S. Karthikeyan received the B.E. degree in Electronics and Communication Engineering from Bharathidasan University, Trichy in 2001 and M.E. Applied Electronics from Sathyabama University, Chennai in 2005. Currently he is a PhD Research Scholar at Department of Electronics and Communication Engineering, Indian Institute of Technology, Guwahati. His research interests include Electromagnetic Band Gap substrates, Microwave Filters and Metamaterials.