Faculty of Electronic and Computer Engineering

BEAM STEERING CONTROL OF MICROSTRIP PATCH ANTENNA USING ELECTROMAGNETIC BAND GAP

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DECLARATION

I declare that this thesis entitled "Beam Steering Control of Microstrip Patch Antenna Using Electromagnetic Band Gap" is the result of my research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : .....

Name : Muhannad Kaml Abdulhameed

Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : …….

Supervisor Name : Dr. Mohd Sa'ari Bin Mohamad Isa

Date : …….

DEDICATION

Dedicated to Allah S.W.T. Almighty and Rasulullah S.A.W. Thanks also

To my father

For earning an honest living for us and for supporting and encouraging me to believe in myself

To my mother

A strong and gentle soul who taught me to trust in Allah, believes in hard work and thought so much could be done with less

To my brothers and sisters

To my wife and my son

The reason of what I have become today

Thanks for your great support and continuous care

ABSTRACT

The use of a high-performance antenna is very important in any wireless system design. The microstrip patch antenna has been employed commonly for numerous wireless applications because of easy analysis and fabrication. It has many advantages, namely, a low profile, low cost, and light-weight. The compact microstrip patch antennas have been achieved by high and thick dielectric substrates. However, this excites the problem of surface waves, thus antenna performance is diminished, especially when changing the main lobe direction of the radiation pattern (beam steering). Mushroom-like EBG structures have attracted increasing interest because of their desirable properties such as high impedance surface for suppressing surface waves. The main problem of the mushroom-like EBG structure is the manufacturing cost and complexity due to the number of vias connecting between the EBG and the ground plane. By loading the EBGs periodically on the substrate, a band gap can be created for frequencies around the operating frequency of the antenna (6 GHz). Such structure can stop the propagation of surface waves along the high dielectric substrate material. Therefore the integration of the mushroom-like EBG structure with a patch antenna and an array antenna of high dielectric constant substrates have been done to improve their performance. By replacing every four cells of the mushroom-like EBG by the one cell of Triple Side Slotted EBG (TSSEBG), reduction in the number of vias has been achieved. The design of TSSEBG with a microstrip patch antenna array showed an enhancement in the gain (from 10.91 to 14.68) dB, directivity (from 11.65 to 15.3) dBi, efficiency (from 84% to 87%), a reduction in side lobe (from -17.9 to -27.5) dB, and reduce the number of vias from 392 to 92. Additionally, a compact EBG based antennas were proposed by combining a rectangular antenna and ideal switches with a mushroom-like EBG structure and with TSSEBG to conduct the beam steering at the E - plane and H-plane, by using band stop and band pass properties, thereby yielding the beam steering into the band pass sector. The number of vias has been reduced from 164 to 40 in the case of combining the TSSEBG with rectangular antenna and ideal switches. The improvement in gain (10.16 dB), directivity (10.5 dBi), and efficiency (93%) have been realized at 0^o main lobe direction. The efficiency is 90.5%, the gain and directivity are 9.67 dB and 10.1 dBi respectively at $\pm 20°$ E-plane direction. In the H-plane radiation pattern control, the efficiency is 89 %, the gain is 9.5 dB, and directivity is 10 dBi at $\pm 18°$ main lobe direction. The simulation results using CST software have illustrated the EBG characteristics of controlling the antenna and array radiation. In order to confirm the simulation results, the antennas are fabricated. The measured results agree well with the simulation data. The proposed antennas can be used in satellite and wireless applications.

ABSTRAK

Penggunaan antena berprestasi tinggi sangat penting dalam sebarang reka bentuk sistem wayarles. Antena tampalan jalurmikro telah digunakan secara umum untuk pelbagai aplikasi wayarles kerana analisis dan fabrikasi yang mudah. Ia mempunyai banyak kelebihan, iaitu, rendah profil, kos rendah, dan ringan. Antena tampalan jalurmikro padat telah dicapai melalui substrat dielektrik yang tinggi dan tebal. Walau bagaimanapun, ini mengujakan masalah gelombang permukaan, oleh itu prestasi antena berkurangan. terutamanya apabila menukar arah aliran utama corak radiasi (haluan pancaran). Struktur EBG seperti cendawan telah menarik peningkatan minat kerana sifatnya yang diingini seperti permukaan impedans yang tinggi untuk menindas gelombang permukaan. Masalah utama struktur EBG seperti cendawan adalah kos pengeluaran dan kerumitan disebabkan oleh bilangan vias yang menghubungkan antara EBG dan permukaan tapak. Dengan memuatkan EBG secara berkala ke atas substrat, jurang jalur dapat dicipta untuk frekuensi disekitar frekuensi operasi antena (6 GHz). Struktur sedemikian dapat menghentikan penyebaran gelombang permukaan di sepanjang bahan substrat dielektrik yang tinggi. Oleh itu integrasi struktur EBG seperti cendawan dengan antena tampalan dan antenna jajaran substrat tetap dielektrik tinggi telah dilakukan untuk meningkatkan prestasi mereka. Dengan menggantikan setiap empat sel EBG seperti cendawan oleh satu sel EBG Tiga Slot Sebelah EBG (TSSEBG), pengurangan bilangan vias telah dicapai. Reka bentuk TSSEBG dengan jajaran antena tampalan jalurmikro menunjukkan peningkatan dalam dapatan (dari 10.91 kepada 14.68) dB, pengarahan (dari 11.65 kepada 15.3) dBi, kecekapan (dari 84% kepada 87%), pengurangan gangguan sisi (dari -17.9 kepada -27.5) dB, dan mengurangkan bilangan pin dari 392 kepada 92. Tambahan lagi, antena berasaskan EBG padat dicadangkan dengan menggabungkan antena segi empat tepat dan suis ideal dengan struktur EBG seperti cendawan dan dengan TSSEBG untuk menjalankan pengimbasan pancaran utama di paksi-E dan paksi-H, dengan menggunakan sifat jalur henti dan jalur lepas, dengan itu menghasilkan haluan pancaran ke dalam sektor jalur lepas. Bilangan vias telah dikurangkan daripada 164 kepada 40 dalam hal menggabungkan TSSEBG dengan antena segi empat tepat dan suis ideal. Peningkatan dalam dapatan (10.16 dB), pengarahan (10.5 dBi), dan kecekapan (93%) telah direalisasikan pada 0^{o} arah aliran utama. Kecekapannya adalah 90.5%, dapatan dan pengarahan adalah 9.67 dB dan 10.1 dBi masing-masing pada $\pm 20°$ arah paksi-E. Di dalam kawalan corak radiasi paksi-H, kecekapannya adalah 89%, dapatannya adalah 9.5 dB, dan pengarahan adalah 10 dBi pada $\pm 18°$ arah aliran utama. Hasil simulasi menggunakan perisian CST telah menggambarkan ciri-ciri EBG dalam mengawal radiasi antena dan jajaran. Untuk mengesahkan keputusan simulasi, antena telah difabrikasi. Hasil yang diukur sepadan dengan baik dengan data simulasi. Antena yang dicadangkan boleh digunakan dalam aplikasi satelit dan tanpa wayar.

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