Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 5 [6] May 2016: 11-14

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.533
Universal Impact Factor 0.9804

ORIGINAL ARTICLE **OPEN ACCESS**

Enhancing Microstrip Patch Antenna Performance by using High Impedance Surfaces (HIS)

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ABSTRACT

Microstrip patch antenna is a simple, low profile antenna,which is suitable for many applications such as mobile, aircraft and missile and due to the ease manufacture, is inexpensive compared with other types of antennas. However, low gain, low radiation efficiency and limited bandwidth of operation are some limitations of this type of antenna. In this study, high impedance surface structure as a type of electromagnetic band gapes structure (EBG) in patch antenna is proposed which is able to suppress surface wave effects. HIS patch antenna reduces level of surface modes compared to conventional patch antenna, thus improve the gain and radiation efficiency.
Keywords: high impedance surfaces, Microstrip patch antenna

Received 02.03.2016 Revised 11.04.2016 Accepted 05.05.2016

INTRODUCTION

A patch microstrip antenna is a type of radio low profile antenna with narow band and high Q factor which can be constructed on a flat surface. It consist of a flat rectangular (or square and circular) metallic sheet or ((patch))mounted on a dielectric substrate .Substrate is located over a large metallic sheet called ground plane. If the antenna radiator is so close to the ground plane(thin substrate)it can have the phenomena of unwanted coupling among the elements and multipath interference and produce current along the edges of the ground plane which also radiate. In this case the image currents cancel the current in antenna ,resulting decreasing the radiation efficiency and antenna gain. In the other hand by increasing the space between the patch and ground plane (thick substrate) may result better efficiency and gain but larger antenna size.[1]

Recently, using artificial periodic structure materials"metamaterials" specially electromagnetic band gaps PBG are developed in any scientific application such as microwave antenna design to obstacle some problems about antenna performance. Nowadays, three main classifications of EBGs like defected ground structures DGS, photonic band gap structures PBG and high impedance electromagnetic surfaces HIES are wildly used in antenna design. High impedance electromagnetic surface is a new type of electromagnetic structures that is made of continuous metal conducting DC currents and does not conduct AC current within a forbidden frequency band. Unlike common conductors this new surface does not support propagating surface waves and reflects electromagnetic waves with no phase reversal.[2,3]

High-impedance surfaces

By incorporating a special texture on a conductor, it is possible to alter its radiofrequency surface properties. In the limit where the period of the surface texture is much smaller than the wavelength, the structure can be described using an effective medium model, and its qualities can be summarized into a single parameter, the surface impedance. This boundary condition defines the ratio of the tangential electric field to the tangential magnetic field at the surface. a flat metallic sheet has low impedance surface but with a specially designed geometry, the textured surface can have high surface impedance.

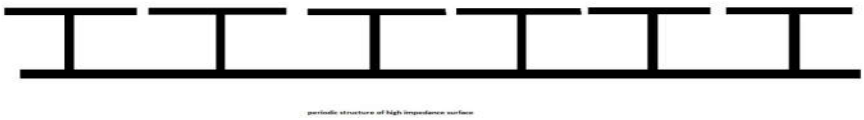


Figure 1. Cross-section of a high-impedance surface

A high impedance surface, shown in figure **1**, consists of an array of metal protrusions on a flat metal sheet. They are arranged in a two-dimensional lattice, and are usually formed as metal plates, connected to the continuous lower conductor by vertical posts. They can be visualized as mushrooms or thumbtacks protruding from the surface. If the protrusions are small compared to the wavelength, their electromagnetic properties can be described using lumped circuit elements – capacitors and inductors. High impedance surfaces act as a simple LC circuit and as it is shown in figure **2**. The proximity of the neighboring metal elements provides the capacitance, and the long conducting path linking them together provides the inductance. They behave a parallel resonant LC circuit and act as an electric filter to block current among the sheet.[6].

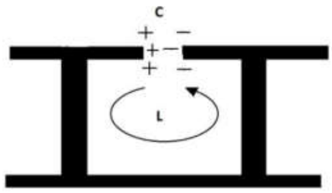
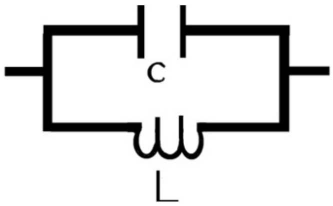


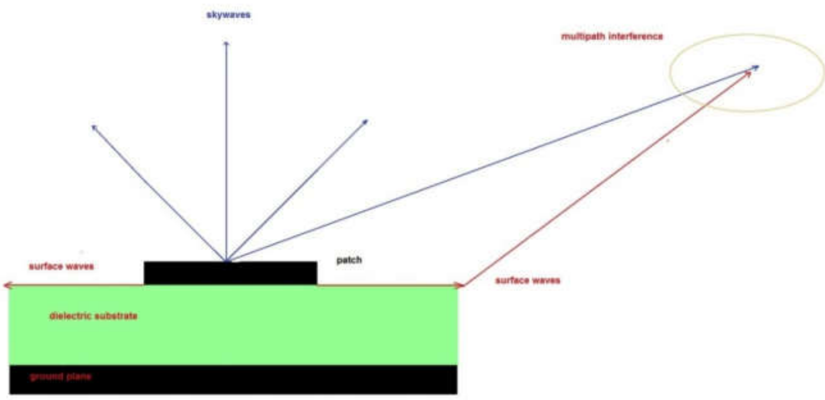
Figure 2: capacitance and inductance in hi equivalent circuit



Figur3: Equivalent circuit of lc circuit

Surface waves

Surface waves exist in many antennas. Surface waves radiate electromagnetic wave propagation along the ground plane instead of into wanted direction and cause unwanted coupling among elements and multipath interference as is shown in figure 4. These problems reduce antenna gain and radiation efficiency. The diffraction of surface waves increases the back lobe radiations, which may deteriorate the signal to noise ratio in wireless communication systems such as Gps receiver.



Figur4:Sky waves, surface waves and multipath interference in patch antenna.

Surface waves raise the mutual coupling levels in array designs, resulting in the blind scanning angles in phased array systems. The band-gap feature of EBG structures has found useful applications in suppressing the surface waves in various antenna designs. For example, an EBG structure is used to surround a Microstrip antenna to increase the antenna gain and reduce the back lobe. In addition, it is used to replace the quarter-wavelength choke rings in GPS antenna designs.[2,7]
The properties of the new high-impedance surface are similar to those of the corrugated slab. The quarter-wavelength slots have simply been folded up into lumped elements, capacitors and inductors that are distributed in two dimensions. The two-dimensional array of resonant elements can be explained using a simple circuit model. The capacitance is due to the proximity of the top metal patches, while the inductance originates from current loops within the structure. The electromagnetic properties of the surface can be predicted by using an equivalent LC circuit, shown in figure 3. The impedance of a parallel resonant LC circuit, given in Eq. 1, is qualitatively similar to the tangent function that describes the impedance of the corrugated surface.

$$.Z_S = j\omega l / 1 - \omega^2 LC \qquad (1)$$

It is inductive at low frequencies, and thus supports TM surface waves. It is capacitive at high frequencies, and supports TE surface waves. In a narrow band around the LC resonance, the impedance is very high. In this frequency range, currents on the surface radiate very efficiently, and the structure suppresses the propagation of both types of surface waves. Having high surface impedance, it also reflects external electromagnetic waves without the phase reversal that occurs on a flat conductor. By using lumped elements, we retain the reflection phase and surface wave properties of the quarter-wave corrugated slab, while reducing the overall thickness to a small fraction of a wavelength [10-11].

Surface waves improvement by using HIS

A high-impedance surface, shown in figure 18, consists of an array of metal, protrusions on a flat metal sheet. They are arranged in a two-dimensional lattice, and are usually formed as metal plates, connected to the continuous lower conductor by vertical posts. They can be visualized as mushrooms or thumbtacks or other shapes protruding from the surface. High Impedance Surfaces as two dimensional EBG structures can be used as microstrip antenna substrate to eliminate the surface wave [8]. Surface waves are excited on microstrip antenna when the substrate $\varepsilon_r > 1$. Besides end fire radiation, surface waves give rise to coupling between various elements of an array. Surface waves are launched into the substrate at an elevation angle θ lying between π / 2 and $sin^{-1} (1/ \varepsilon^{1/2})$. These waves are incident on the ground plane at this angle, get the reflected from there, then meet the dielectric-air interface, which also reflect them. Following this zig-zag path, they finally reach the boundaries of the microstrip structure where they are reflected back and diffracted by the edges giving rise to end-fire radiation [9]. On other way in the boundary, if there is any other antenna in proximity, the surface wave can become coupled into it. Surface waves will decay as $\boldsymbol{1/ \varepsilon^{1/2}}$ so that coupling also decreases away from the point of excitation. Surface wave are TM and TE modes of the substrate.

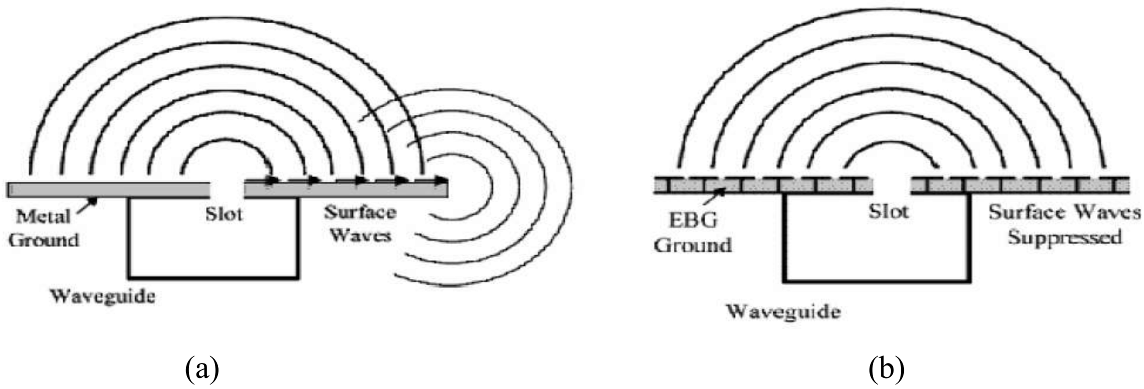


Figure 5: substrate without EBG structure (a) and with EBG(B).

These modes are characterized by waves attenuating in the transverse direction (normal to the antenna plane) and having a real propagation constant above the cut-off frequency. The phase velocity of the surface waves is strongly dependent on the substrate parameters h and ϵr. Figure 5 shows the propagation of the surface wave in Micro strip antenna [8].

CONCLUSION

We have seen that while ground plane as a reflector in patch antenna is useful, it also has several problems, such as permitting surface waves to propagate and a phase reversal for reflected plane waves that cause negative effects on antenna performance. Surface waves produce unwanted coupling and multipath interference resulting decrease in antenna gain and efficiency. Recently a new material called high impedance surfaces are developed as a useful way to obstacle this problems. High impedance surfaces conduct DC currents but does not conduct AC currents through a special rang of frequency .high impedance surfaces act like as a resonant LC circuit with inductive and capacitive properties. HIS's as a ground plane unlike conventional metallic planes does not allow to surface waves to propagate. Surface waves suppression by HIS's improve the performance of antenna by enhancing the gain and radiation efficiency of antenna.

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CITATION OF THIS ARTICLE

Omid Mahmoodian. Enhancing micro strip patch antenna performance by using high impedance surfaces (HIS). Bull. Env. Pharmacol. Life Sci., Vol 5 [6] May 2016: 11-14

