NOVEL SURFACE WAVE ANTENNAS FOR WIRELESS COMMUNICATIONS

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1. INTRODUCTION

The developments of microstrip antennas and dielectric resonant antennas, which smartly exploit the unwanted radiation in microwave circuits to built efficient radiators, have illustrated the ingenuity of antenna designers. This paper presents another example: a novel surface wave antenna design. Surface waves are unwanted by-products in many antenna designs that degrade the antenna performance. However, if surface waves are properly controlled, they can be utilized to build promising antenna structures. The surface wave antenna (SWA) concept was introduced in 1950's [1]-[3]. In this paper, we revisit the SWA concept and present a novel SWA design. Compared to traditional SWAs, the new design has an attractive low profile configuration, which is desirable in modern wireless communication systems.

The important advancement of the SWA is achieved by implementing a novel artificial ground plane. In recent years, complex artificial surfaces have been investigated extensively and utilized to replace the conventional perfect electric conductor (PEC) surface in various microwave and antenna devices. Representative examples include frequency selective surfaces (FSS), soft/hard surfaces, electromagnetic band-gap (EBG) structures, and artificial magnetic conductors (AMC). These artificial surfaces exhibit diverse boundary conditions for electromagnetic waves, which have led to a wide range of applications in antennas, microwave circuitry, electromagnetic compatibility, and radar systems (See special issue [4]).

2. CHARACTERIZATIONS OF COMPLEX ARTIFICIAL GROUND PLANE

Fig. 1(a) shows a complex artificial ground plane: a grounded dielectric slab loaded with periodic square patches. Compared to a soft/hard surface [5], it is a two dimensional periodic structure. It is also distinguished from a mushroom-like EBG structure [6] by removing the vertical vias that connect the patches to the ground plane. Important parameters of an artificial ground plane design include width of the square patch (W), gap width (g), substrate thickness and dielectric constant.

To identify the electromagnetic properties of the structure, the finite difference time domain (FDTD) method is used to simulate its performance. It is revealed in [7] that this artificial ground plane exhibits a similar reflection phase feature to a mushroom-like EBG structure for a normally incident plane wave. It reflection phase decreases continuously from 180° to -180° as frequency increases. However, in contrast to EBG structure, this patch loaded grounded slab does not have a surface wave band gap because of the removal of vertical vias. Instead, the first surface wave mode (TM^z dominant) can exist in a wide frequency range.

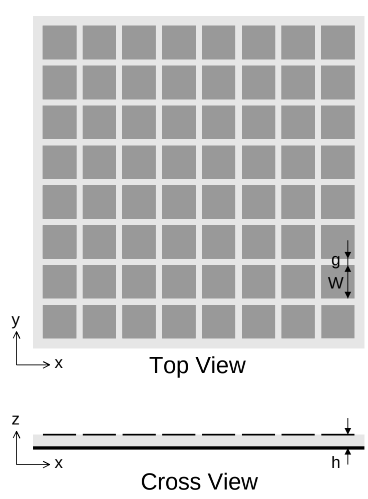


Fig. 1. Geometry of an artificial ground plane: a thin grounded dielectric slab loaded with periodic square patches.

3. A DIPOLE FED SURFACE WAVE ANTENNA

The mushroom-like EBG surface was successfully used as the ground plane for a low profile dipole antenna to radiate efficiently [8] [9]. After discovering the similarities and differences between the patch loaded grounded slab and the EBG surface, it is interesting to examine the performance of a horizontal dipole near the patch loaded grounded slab, as shown in Fig. 2.

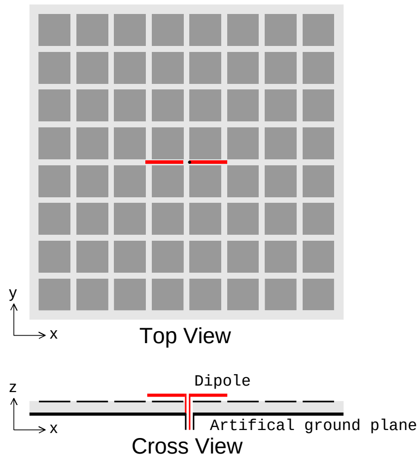


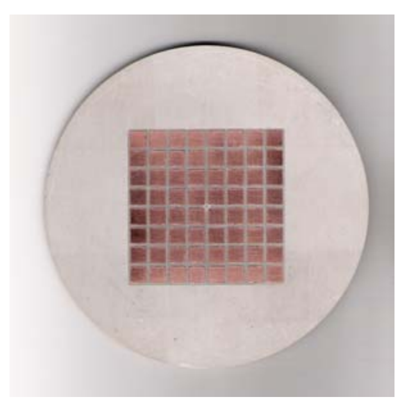
Fig. 2. A horizontal dipole antenna near a patch loaded grounded slab.

Dipoles with various lengths have been tested and it is observed that the antenna radiates efficiently with a length around 0.26 λ [10], which is much smaller than the half wavelength. In addition, this antenna exhibits a monopole type radiation pattern [10] with a null in the broad side direction and E fields polarized along the θ direction. The distinct radiation performance of the antenna can be explained from its operation mechanism. There is no band gap for surface waves in a patch loaded grounded slab. Thus, when a dipole is positioned near this artificial ground plane, strong surface waves are excited and their diffractions at the edge of the ground plane determine the antenna properties. In this design, the dipole works more like a transducer rather than a radiator so that the length of the dipole is not necessarily to be half wavelength. Moreover, the surface waves are dominated by the TM^z modes and the electric field is vertically polarized. The hard diffractions of surface waves from opposite edges will cancel each other in the broadside direction, resulting in a radiation null. The vertically polarized surface waves also determine that the diffraction field must be polarized along the θ direction. Thus, a monopole type radiation pattern is generated. Because of its operation mechanism, this radiating structure can be identified as a surface wave antenna (SWA).

4. PATCH FED SURFACE WAVE ANTENNA EQUIVALENT TO A VERTICAL MONOPOLE

A noticeable defect in the dipole fed SWA is the relatively high cross polarization [10]. To overcome this defect, a patch fed surface wave antenna is proposed, as shown in Fig. 3. The artificial ground plane remains the same and a center fed circular patch is positioned in the middle of the substrate to excite surface waves.

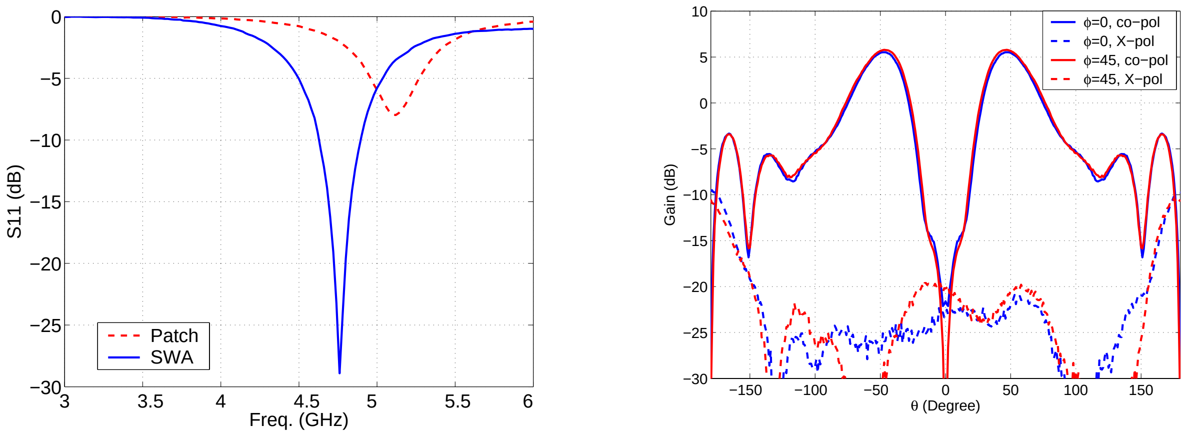
(a)



(b)

Fig. 3. Photos of a patch fed surface wave antenna: (a) a circular patch in the middle layer with a probe connected to its center, and (b) periodic square patch array on the top layer.

The parameters of the artificial ground plane are the same as given in [10], and the circular patch has a radius of 21 mm. The ground plane is truncated to a circular shape to obtain a symmetric diffraction pattern. Fig. 4(a) shows measured return loss results of the surface wave antenna, compared with a conventional center fed circular patch antenna. It is observed that patch antenna has a poor return loss due to the inherent high input impedance. In contrast, the SWA resonates at 4.72 GHz with a good return loss because of the efficient launching of the surface waves in the artificial ground plane. The impedance bandwidth of the SWA is 5.9%. The radiation patterns of the SWA are measured and plotted in Fig. 4(b). The antenna is polarized along the θ direction with a fan beam at θ=46° and a gain of 5.6 dB. The antenna has a deep null in the broad side direction the cross polarization is about 25 dB lower than the co-polarization. Almost identical radiation patterns are obtained in the xz and diagonal planes. In summary, the SWA realizes a radiation pattern similar to a vertical monopole antenna with a significantly reduced antenna height.



(a) (b)

Fig. 4. Radiation performance of the patch fed surface wave antenna: (a) return loss and (b) radiation pattern.

5. CONCLUSIONS.

This paper presents novel surface wave antenna designs using a thin grounded slab with periodic patch loadings. The artificial ground is characterized using the FDTD method and antenna prototypes are designed, fabricated and tested. The surface wave antennas realize a monopole type radiation pattern with a winning low profile configuration, which have a great potential for wireless communications such as vehicle radio systems.

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Surface wave antennas have been investigated extensively as it can be introduced into modern wireless communication device to improve the performance [11]. It can has a low profile and maintains the high performance [12] by increasing the effective area to reduce the beamwidth [13]. Beam-steering Surface Wave Fluid Antennas for MIMO Applications. Article. Jan 2020.Â A novel planar leaky-wave antenna of conductor modulating periodic structure for millimeter wave application is proposed. Using the theory of two-dimensional periodic admittance surface, theoretical analysis, numerical calculation and experimental study are carried out for this kind of antenna. A planar antenna of conductor modulating periodic structure is realized in 8mm wave band. @article{Leong2001SurfaceWE, title={Surface wave enhanced broadband planar antenna for wireless applications}, author={K. Leong and Y. Qian and T. Itoh}, journal={IEEE Microwave and Wireless Components Letters}, year={2001}, volume={11}, pages={62-64} }. K. Leong, Y. Qian, T. Itoh. Published 2001. Engineering. IEEE Microwave and Wireless Components Letters. This letter explores the development of a new class of broadband antenna in which TE/sub 0/ surface-wave is used as the primary source of free space radiation. We demonstrate that antennas based on this concept can be designed to operate over a broad bandwidth, be extremely compact, and can be easily integrated with MIC and MMIC technology. wave antennas have relatively narrow bandwidth, typically of only a few percent. However, given that wireless communications systems do not need a simultaneous wide bandwidth, a frequency reconfigurable (tunable) leaky wave antenna would serve as a good candidate for many applications. This paper aims to provide an overview of the development of reconfigurable leaky wave antennas.