EXPERIMENTAL PHASE PLATE EMPLOYING A PHASE MODULATED ACTIVE FREQUENCY SELECTIVE SURFACE

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ABSTRACT: A novel method employing a phase modulated frequency selective surface (FSS) to improve the wireless communications coverage of enclosed spaces in the built environment through the filling of black spots is described. The design and fabrication of a phase modulated FSS are discussed, together with some initial measurements and results.

Key words: frequency selective surface (FSS); active FSS; phase modulation

1. INTRODUCTION

This article presents a novel technique whereby an active FSS is used to modify and enhance the wireless communications coverage within enclosed spaces, such as buildings, tunnels, or enclosures [1]. Propagation in these environments can often result in unwanted effects adversely affecting the wireless coverage in that space, particularly where no direct line-of-sight path exists between the wireless equipment. In these instances, achieving adequate signal strength often relies upon combinations of propagation modes, reflection, diffraction, and scattering, with the potential for multipath signals creating wireless black spots or nulls by phasor field cancellation. These nulls can be quite deep and very localized, resulting in reduced field strengths and even total signal outage. Previous work has demonstrated that an improvement in the carrier-to-interference ratio of about 15 dB yields a reduction by a factor of almost 30 in the outage probability [2]. An added complication is that these environments are often dynamic, with the movement of equipment, furnishings and people continually changing the propagation characteristics of that space. The technique described here enables propagation path lengths to be modified, resulting in the filling of these nulls and, therefore, smoothing the spatial distribution of the signal, and consequently, improving wireless coverage of these environments.

2. PHASE MODULATED SURFACE

Described in [3, 4] is a planar screen for radar signature management, the same basic technique that is used in this application. The structure uses a phase modulated active FSS (AFSS) spaced some fixed distance d from a solid conducting surface as shown in Figure 1. Although the latter is metallic here, in general it could be frequency selective [5], allowing plate transparency for example, at selected frequencies. With the structure illuminated by a plane wave incident at an angle θ to the normal, and the medium between the two surfaces with a relative permittivity ε_r, the phase difference [5] between the two reflected signals at a wavelength λ is 2 dβ, where $\beta = (2\pi/\lambda)\sqrt{(\varepsilon_r - sin^2\theta)}$. By switching the AFSS at a suitable rate between these two states, the resultant reflected signal will be phase modulated. It is considered in this application that the structure would be a plate, or multiple plates, of a shape and size determined by its intended environment and, therefore, from here on in the structure will be referred to as a phase plate.

3. EXPERIMENTAL PHASE PLATE

The phase plate structure is shown in Figure 2. A technique described in [6] is used for two-state switching of a linear dipole array AFSS utilizing PIN diodes as the switching element. By application of a forward or reverse DC bias, the surface can be reflective or transparent at its resonant frequency. Targeting the WLAN band of 2.45 GHz, an AFSS was initially modeled and simulated using CST Microwave StudioTM. The simulations included the equivalent circuit model for the selected PIN diodes as their off capacitance had a significant effect, loading the dipoles and consequently shortening them when compared with their free-space length. RF chokes were used on the end elements to isolate the bias lines. They were chosen to have significant inductive reactance (_200 X) at the frequency of operation whilst keeping their self resonant frequency (SRF) above that of the AFSS. The resulting AFSS was a 6 × 5 array of linear dipoles etched on a 0.125-mm-thick mylar substrate (ε_r ~ 3.2) with each dipole being 42 mm long arranged in rows spaced at 30 mm. The PIN diodes series connect the ends of adjacent dipoles. The conductive surface place behind the AFSS consisted of a sheet of copper foil with a 12 mm thick supporting polystyrene foam sheet (ε_r ~ 1) filling the void between it and the AFSS.

4. MEASUREMENTS AND RESULTS

The preliminary measurement system consisted of a plane wave chamber equally divided by a rotatable, RF absorber loaded screen with a centrally located aperture to accept the surface under test. With the phase plate placed in the aperture, it was illuminated with a normally incident ($\theta = 0°$) plane wave. The measured results are shown in Figure 3. The surface displayed a resonance at 2.42 GHz and a total phase shift of 70° when switched between its two states by application or removal of the DC bias. This compares well with the calculated path length phase. By modifying the system to that of Figure 4 a multipath experiment was carried out. The illuminating source now also excited a second antenna via a -3dB power splitter. The second antenna could be positioned whilst monitoring the RF level along P to check the presence of multipath nulls. With the secondary antenna suitably located and the phase plate in its off state the receiver antenna was placed in a null along P, the observed signal level in this case being buried within the noise floor of the measurement receiver/spectrum analyser. Applying the bias to the diodes raised the signal level to a point some 20 dB above the noise floor, demonstrating that the null had been filled at that point. The experimental results are shown in Figure 5, where the signal enhancement at 2.42 GHz can clearly be seen. In practice the plate would be rapidly switched periodically, smoothing the overall spatial distribution in, for example a building, and filling the nulls.

5. CONCLUSIONS

This letter has shown how an AFSS and a reflecting surface may be combined and modulated to form a phase plate. A phase plate makes it possible to remove wireless coverage nulls in enclosed environments resulting in an improved signal distribution in that space. It would have applications in improving wireless coverage in both dynamic and static environments. In its present form, the plate has been modulated at very slow rates as a proof of concept.

ACKNOWLEDGMENT

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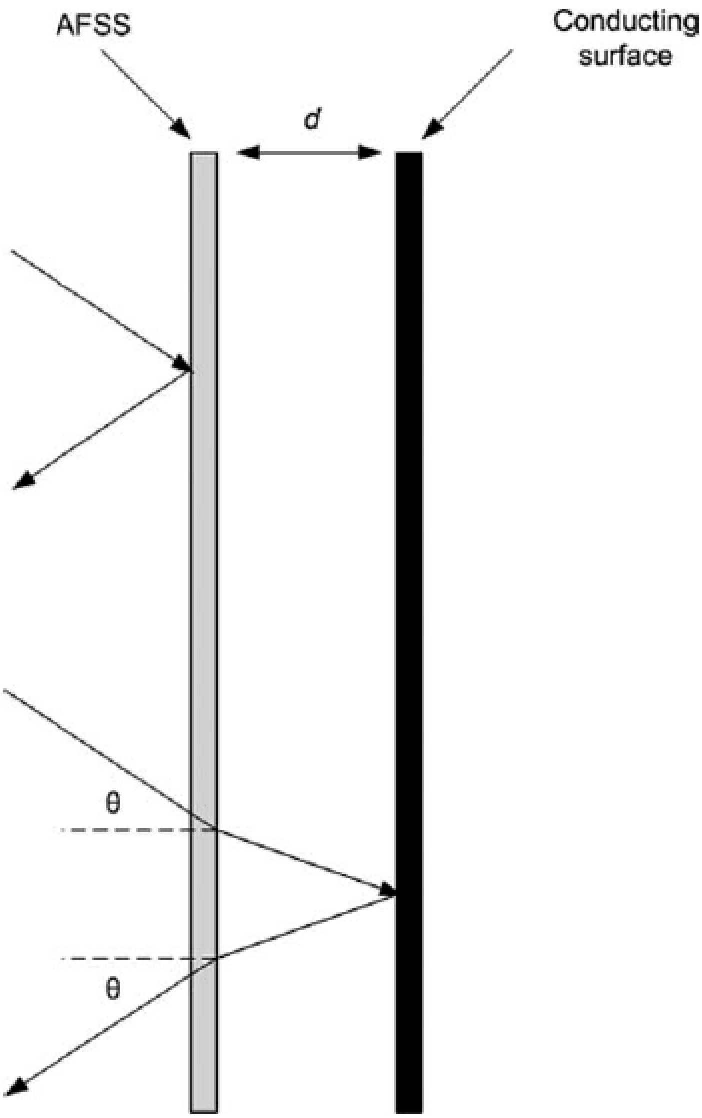

Figure 1 Phase modulated structure

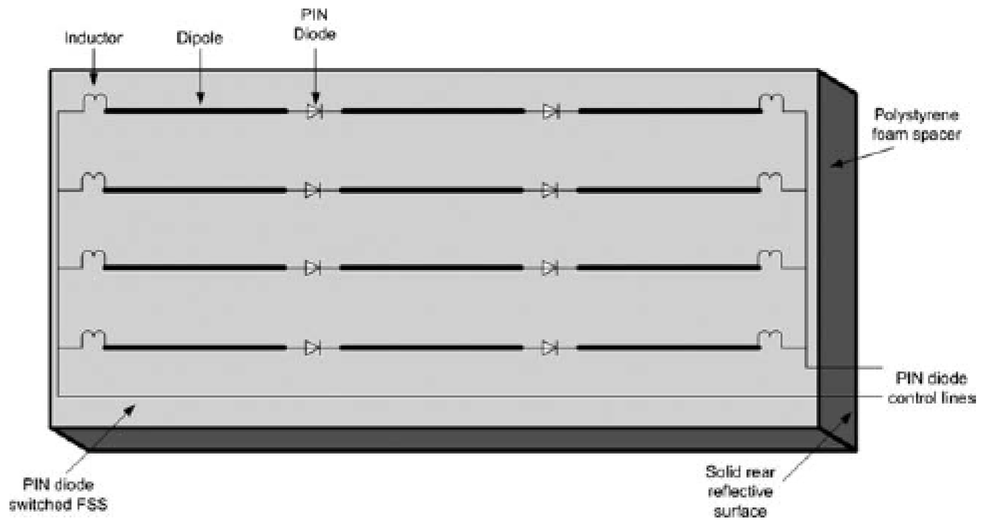

Figure 2 Experimental phase plate

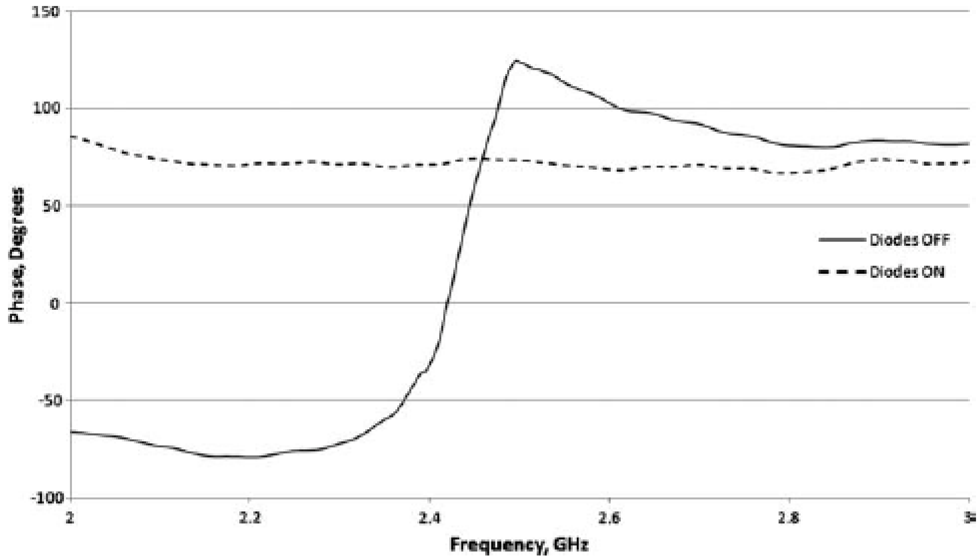

Figure 3 Two-state switching results for the experimental phase plate

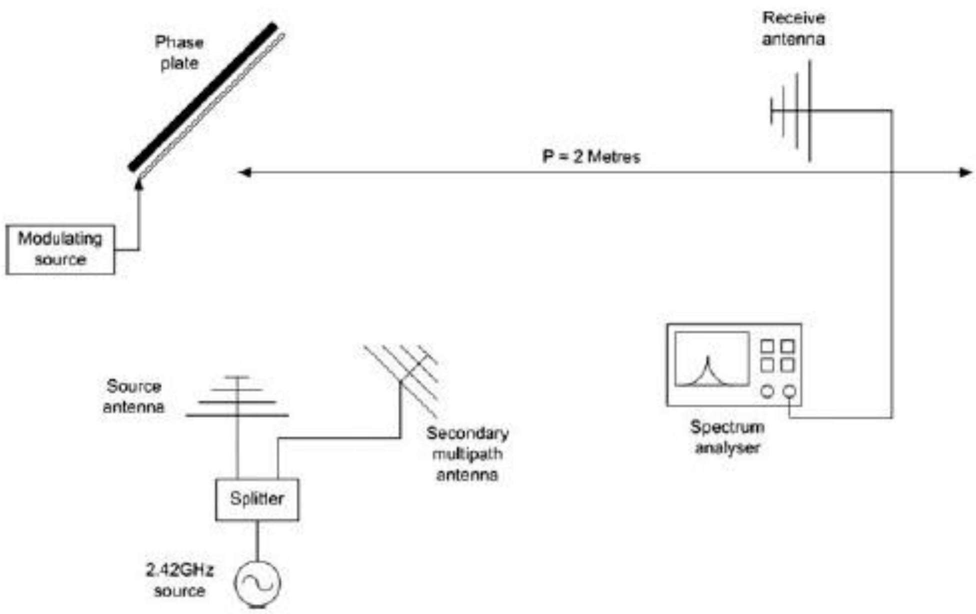

Figure 4 Experimental set-up for the producing and removal of multi-path nulls

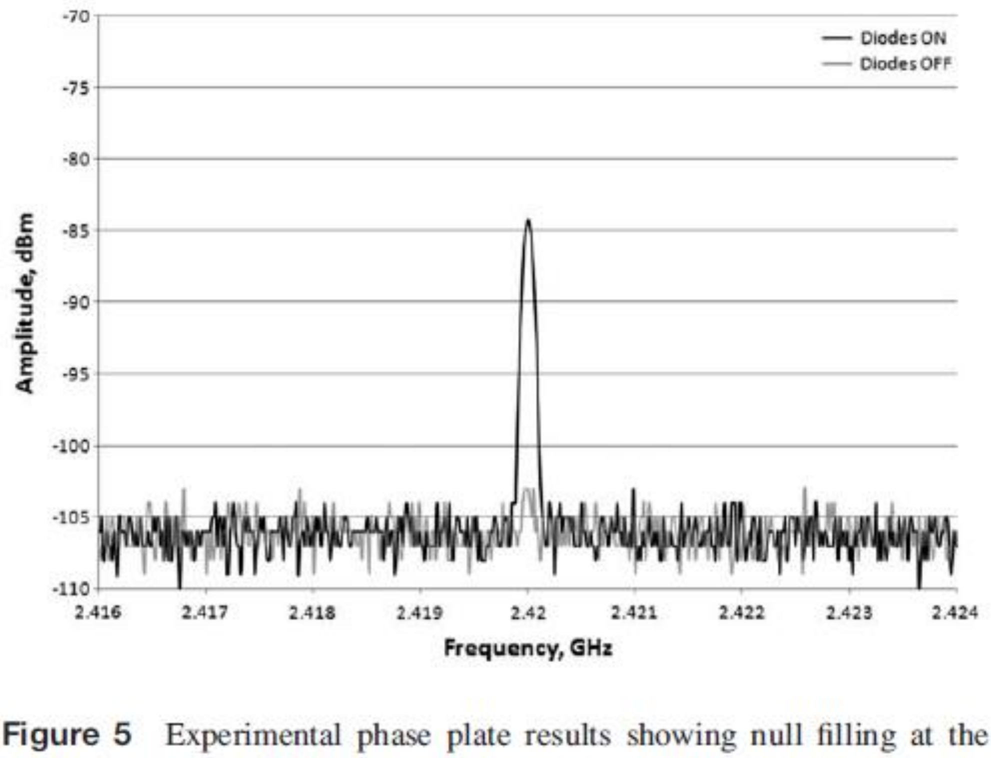

Figure 5 Experimental phase plate results showing null filling at the design frequency of 2.42 GHz