Tuning patch-form FSS

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Abstract:

The application of a novel biasing technique to tune frequency selective surfaces (FSS) made of patch elements is described. The methodology follows a recently developed technique where the biasing circuit of an active FSS is etched at the rear of a double sided substrate. On this occasion, the structure consists of dipole patches on one side of the thin polyester substrate and the biasing circuit at the rear, electromagnetically hidden by the patches. Varactor diodes are employed to modify the capacitance between the patches. The novel active FSS structure is able to tune a bandstop filter response over a wide frequency range, which could suit applications such as the time dependent modification of the EM architecture of buildings.

Introduction: The increasing saturation of the radio spectrum, particularly in indoor applications, has led to a significant growth in projects applying frequency selective surfaces (FFS) to the built environment [1, 2]. The FSS designs for this purpose may well need to cover a very wide frequency band [2], typically ranging from 300 MHz to

6 GHz. Time dependent modification of the propagation in the built environment can be achieved using active frequency selective surfaces (AFSS). Internal areas within the building can be dynamically screened using them, enhancing the capacity for frequency reuse. An active frequency selective wall with two states of operation was described in [3]. The wall was covered by an active frequency selective surface consisting of linear dipole patches with pin diodes connecting the ends of adjacent elements. The electromagnetic transparency of the wall was controlled by switching the diodes between their ON and OFF states. Tunable FSS structures on the other hand can offer a gradual modification of the transmission response. In [4], the tuning patch-form FSS was achieved using varactors and transmission lines etched on the same layer. In that paper, the ratio of the resonant frequencies at maximum and minimum bias voltage values across the varactors was around 6%, a modest tuning ratio. The biasing lines extended along the surface, limiting the number of geometries to which the technique can be applied. Similar configurations were described in [5–7], all employing cells with patch pairs and varactors connecting them. There, vias were

employed to connect the biasing circuit to external DC control. A more elaborated configuration for mushroom-type high impedance surfaces was presented in [8], where the vias of the HIS were used as part of the biasing circuit. In this Letter a two-layer tunable FSS structure is proposed. It applies the technique described in [9], here to patch-form FSS where biasing lines can often be largely hidden. This configuration offers an alternative to schemes employing vias, and is also wideband. The structure consists of patch elements on one side, the biasing circuit on the other side and a very thin flexible dielectric material sandwiching both. The tracks of the biasing circuit are placed at the rear of the patches, minimising the effect of the biasing circuit on the transmission response. Wideband tuning is achieved using this novel active FSS configuration.

Design: Figs. 1a and b illustrate the front and the rear of the active FSS structure. The FSS consisted of an array of thick (l/w = 1.9) linear dipoles, etched on one side of a dielectric substrate of 0.05 mm thickness, copper clad on both sides, and relative permittivity 3. Varactor diodes and chip resistors were mounted on the tracks etched on the other side of the substrate, BB857 silicon diodes with a tunable capacitance range 0.5 pF (28 V) to 7.2 pF (1 V). 10 kΩ surface mount resistors were included. The biasing circuit was designed so that the voltage drop across every resistor was insignificant compared with the voltage across the varactors, allowing tuning with approximately the same potential in every single diode. A varactor and two resistors were located in the gap between adjacent dipole patches. A cross-sectional view of this biasing configuration is shown in Fig. 1c. The tunable array consisted of 10 × 6 dipole patches with an independent biasing circuit for every column. The dipole elements were 19 mm long (l) and 10 mm wide (w), arranged in columns spaced 30 mm apart. There was a 1 mm gap between every adjacent patch. The width of the tracks that made up the biasing circuit was d = 2 mm. The initial dimensions of the patches were calculated using CST Microwave Studio™ and the active components were added to the simulations as lump elements.

Experimental results: Measurements were carried out using two log periodic antennas at approximately 0.6 m from a 1.52 × 1.95 m absorbing screen containing an aperture of 19 × 19 cm, where the FSS was inserted. With linear dipole elements, this design was singly polarised. The measured transmission response of the AFSS at normal incidence for 5, 10, 15, 20 and 28 V across the varactors is shown in Fig. 2. As voltage increased, the capacitance of the varactors decreased, thereby decreasing the capacitance between adjacent dipole patches and increasing the resonant frequency of the stop-band filter. The corresponding resonant frequency for different voltage values was approximately 1.5 GHz at 5 V, 2.6 GHz at 10 V, 2.7 GHz at 15 V, 2.9 GHz at 20 V and 3.1 GHz at 28 V. At 28 V, transmission levels were above 210 dB at frequencies below 2.5 GHz. In contrast, attenuation levels were over 15 dB between 1.3 and 2.5 GHz at 5 V. The resonant frequency changed between 5 and 28 V by a factor of 2, showing the capability of this structure to tune over a wide band. The changes in the resonant frequency for different voltage values corresponded closely to the capacitance against voltage characteristic of the varactor diode, including the large change between 5 and 10 V.

The angle of incidence behaviour of the active FSS at TE45 and TM45 is shown in Figs. 3 and 4. The resonant frequency did not vary significantly at TE45, while the 210dB fractional stopband width increased by 15% at 5 V and 73% at 28 V. At TM45, the measured resonant frequency increased, by over 40% at 5 V and 32% at 28 V, while the bandwidth did not vary significantly. The main reason for the behaviour at TE45 and TM45 is that while the gap between adjacent dipoles was just 1mm, the columns were widely spaced, by 30mm, and it is well known that the lattice geometry has a major influence on this [10]. For example, simulations show that a 50% reduction in the distance between the parallel dipoles improves the angular stability at TM45 by a factor of 3. Skewed lattices give more stability.

Conclusions: Tuning over a wide frequency band can be achieved using the novel two-layer design for patch-form active FSS presented here. The structure consists of patterns etched on two metallic layers sandwiching a very thin dielectric substrate, with metallic patches on the front and the biasing circuit hidden immediately behind the patches. An application is the time dependent modification of the propagation of electromagnetic waves in buildings. In addition, it could be employed for high impedance surfaces that do not have vias connected to the ground. The authors are currently investigating dual polarised active FSS using this technique and its application to electromagnetic bandgap structures.

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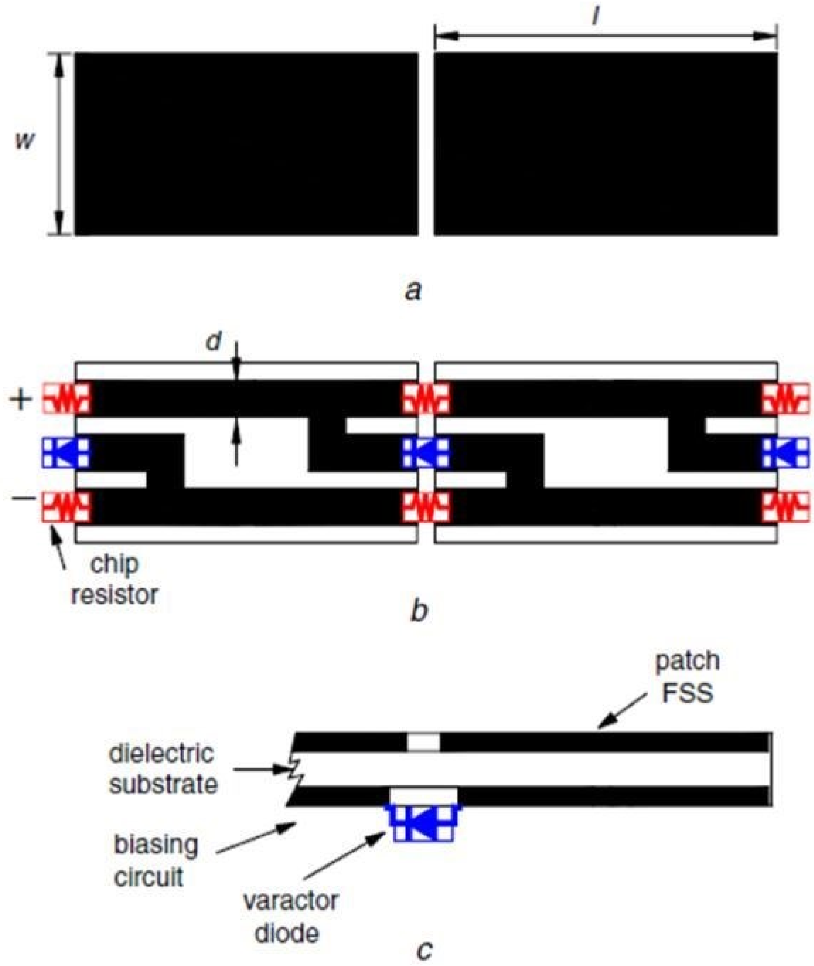

Fig. 1 *Two unit cells of active frequency selective array*

a Front view with thick dipole patches
b Rear view with biasing circuit
c Magnified cross-sectional view

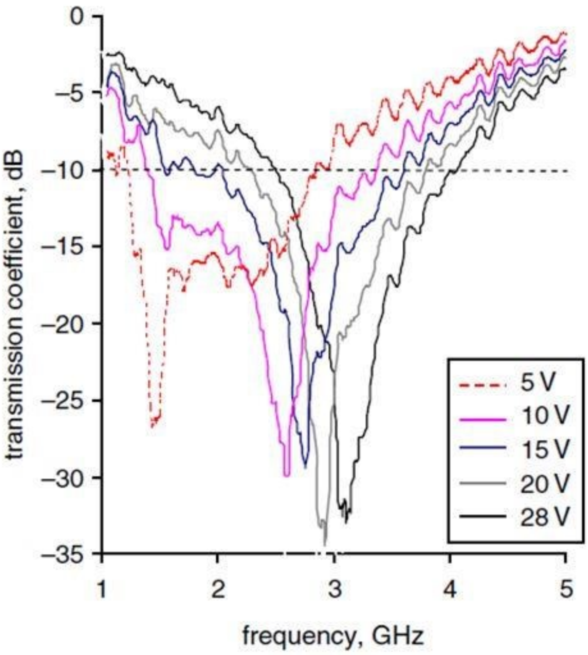

Fig. 2 *Transmission response at normal wave incidence for various diode biasing voltages*

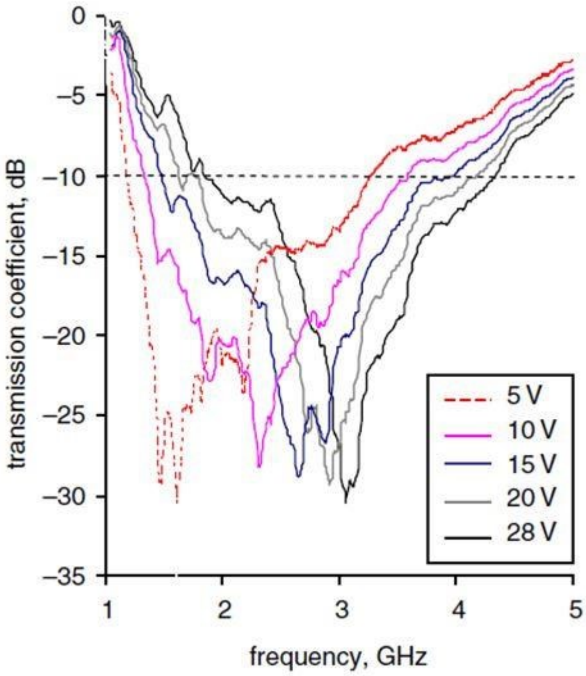

Fig. 3 *Transmission response at TE45*

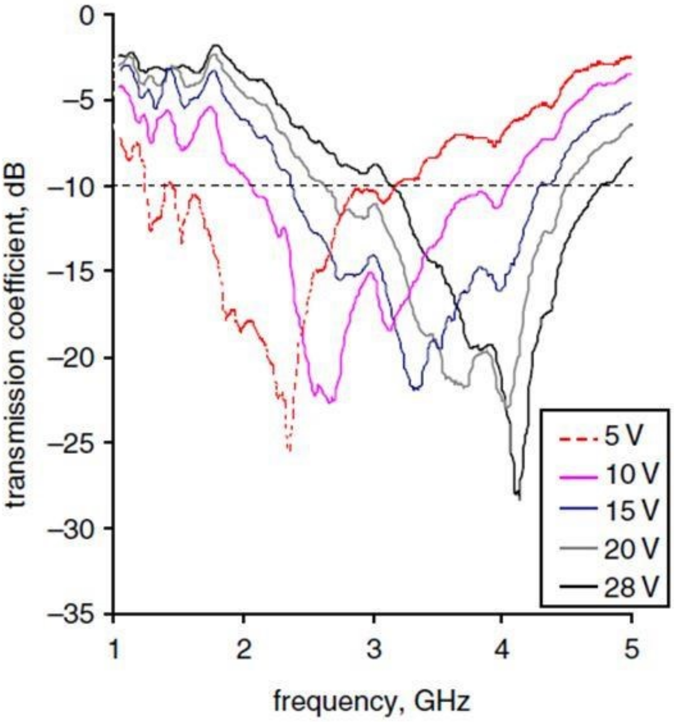

Fig. 4 *Transmission response at TM45*