and 94 GHz image radar systems, and even higher frequency radar systems.

4 | CONCLUSIONS

In this article, we report a high-performance four-stage four-way PA for 77 GHz automobile radar and 94 GHz image radar systems. The PA comprises a two-stage CS cascaded input stage, followed by a two-way cascode gain stage, and a four-way CS output stage. In addition, to replace the conventional area-consuming Wilkinson power divider/combiner or zero-degree divider/combiner, we adopt miniature zero-degree two-way divider and combiner at the gain stage, and miniature zero-degree four-way divider and combiner at the output stage. This in turn results in simpler amplifier architecture and bias arrangement, and prominent performance. The result shows that the PA architecture is promising for V-band and W-band communication systems.

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RFSS based on cross dipole or grid using PIN diode

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Abstract
This work presents an RFSS with two discrete states, corresponding to a pass-band or stop-band response depending on PIN diode biasing. The RFSS behaves as an array of cross dipole elements when all diodes are in the OFF-state and as a grid when the diodes are in the ON-state. The cross dipole patch array has a stop-band filter response and the grid behaves as a pass-band filter at the design frequency of 1.6 GHz. Simulation and measurements of insertion loss are presented, demonstrating the switchable band-pass to band-stop response.

Keywords
AFSS, frequency selective surface, PIN diode, reconfigurable device, RFSS

1 | INTRODUCTION

Typically, frequency selective surfaces (FSS) are two-dimensional periodic arrays that behave as spatial filters. The frequency response of an FSS will behave as a stop-band if the single element of the array is a patch. Analogously, an aperture array element will result in a pass-band response. Variables, such as unit cell geometry, dimension, and periodicity are important factors for determining the FSS frequency response.

An extension of the FSS is the reconfigurable frequency selective surfaces (RFSS). RFSS properties (such as resonant frequency and polarization) can be changed in real time, while passive FSS has constant characteristics. The ability to vary the frequency response can be achieved by introducing active elements into the device, such as the PIN diode, which is commonly used as a switch. PIN diodes are placed as switches along the RFSS structure to provide reconfiguration. An external DC bias is applied to the diodes as forward or reverse bias to define the ON or OFF state of the PIN diodes, respectively. When a diode is forward biased, it creates a new path for current flow, which results in changes over the FSS’s response. MEMS, varactors, and photodiodes can also be used to reconfigure devices.

This paper presents a RFSS whose array consists of cross dipoles connected by PIN diodes. By changing the state of the diodes, the RFSS’s frequency response can be toggled between stop band and pass band. Both configurations operate in dual TE/TM polarization for an orthogonal incident angle. The simulation was held using CST Microwave Studio 2016®. Simulated and measurement results for insertion loss are presented here.

2 | CROSS DIPOLE: GRID RFSS

2.1 | Structure

A cross dipole is shown in Figure 1A. The cross dipole resonates when its length is a half-wavelength. An FSS whose elements are cross dipoles is expected to have a stop-band characteristic response, since the cross dipoles behave like patches. Another possible FSS configuration is the grid configuration, shown in Figure 1B. This time, the FSS unit cell is a grid expected to produce a pass-band response, since its structure is composed by apertures.

The key to achieving the proposed RFSS structure, relies on PIN diode placement at the edge of the cross dipoles, as illustrated in Figure 1C. Notice that when the diodes are in OFF state, there is no current flowing between the cross dipoles.
dipoles. Therefore, the RFSS will behave as a cross dipole FSS (stop-band). However when the diodes are in ON state current flows through the dipoles. Consequently, the RFSS will behave as a grid FSS (pass-band). This simple configuration is remarkably interesting because of its simplicity and also because it allows FSS reconfiguration by a change of filtering function (ie, toggling between pass-band and stop-band responses).

2.2 Circuit bias

The RFSS contains an array of $N \times N$ diodes. The cross dipoles are connected to each other by diodes placed at their edges. By choosing the appropriate diode orientation (see Figure 2) it is possible to switch all diodes with just two DC bias points in the structure (GND and Vcc). The diodes are connected in an orientation that goes from lower voltage to higher voltage, or vice versa, as shown in the Figure 2. The diodes are forward biased or reverse biased, all at once. In order to simplify simulations, the ON-state diode is replaced by a conducting printed strip on the substrate connecting the cross dipoles. Alternatively, the OFF-state diode is represented by a spacing between the cross dipoles, even though this model does not account for diode intrinsic properties, such as resistance and reactance, it provides a first approximation and allows demonstrating the reconfigurable band-pass to stop-band RFSS concept.

3 RESULTS AND DISCUSSION

This section presents the measured and simulated results for the proposed RFSS considering a normal incidence of a vertically polarized plane wave. The simulation of the structure considering open and short circuits replacing the diodes is shown in Figure 3. The center frequency occurs at 2.21 GHz with $S_{21}$ values of $-29$ dB for the OFF-state and $-0.6$ dB for the ON-state, successfully demonstrating the stop-band and pass-band responses of the device, respectively.

In order to validate the simulations, a $4 \times 4$ array (ie, 16 unit cells) version of the RFSS was fabricated as shown in Figure 4. The periodicity of the unit cell is 46.5 mm, the length and width of the cross dipole are 45.5 and 1 mm, respectively. The substrate used was FR-4 ($h = 1$ mm,
\( \varepsilon_r = 4.4, \tan \delta = 0.02 \). An array of 24 diodes (Infineon’s BAR64) is used. The experimental results are obtained using an Agilent E5071C Vector Network Analyzer and two SAS-571 double ridge guide horn antennas. The measurement setup includes a panel with a slot of \( 20 \times 20 \text{ cm} \) to hold the FSS, shown in Figure 5. Absorbers are used to prevent undesired reflection. The dimensions of the RFSS are \( 18.5 \times 18.5 \text{ cm} \). A square copper loop was made around the FSS to provide bias to the diodes and to fill in the slot. The loop was sectioned into two parts, one to provide Vcc and other connected to GND.

Two types of measurement were performed. The first measurement verifies \( S_{21} \) as a function of Vcc, varying from 0 to 5 V, shown in Figure 6. For values of Vcc from 0 to 3 V, the RFSS behaves as a stop band filter. For values of Vcc above 4 V, the RFSS behaves as a pass band filter. The second measurement verifies the behavior of the RFSS for values of Vcc from -5 to 0 V. As shown in Figure 7, there is no apparent change in frequency response when the Vcc is below 0 V.

Experimental measurements show that when the diodes are in ON-state (Vcc = 5 V) the RFSS behaves as a passband (\( S_{21} = -4 \text{ dB at } 1.63 \text{ GHz} \)). When the diodes are in OFF-state (Vcc = 0 V) the RFSS behaves as a stop-band (\( S_{21} = -15 \text{ dB at } 1.63 \text{ GHz} \)). Table 1 presents a comparison between simulated and measured insertion loss. A frequency shift between the simulated and measured results occurred due to the parasitic elements of the diodes.

### 4 | CONCLUSIONS

As shown in both simulated and measured results, the RFSS performs as expected, changing filtering characteristic when its diodes are toggled between ON and OFF states. Experimental and simulated results show a good agreement and demonstrate the versatility of the structure as a reconfigurable filter. However, a shift between experimental and simulated results is presented. This is believed to be due to the use of an ideal short circuit as a model for the diode ON-state. The RFSS behaves as a band-pass filter when the diodes are at ON state. At OFF state, the RFSS behaves as a band-stop filter. Switching Vcc between 0 and 5 V is sufficient to change the filtering characteristic of the RFSS, therefore, the structure can be controlled by ordinary low-power circuits. This structure can be applicable for devices such as adaptive and RFID antennas.

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Small dual-band slot antenna using capacitor loading

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Abstract
A method is proposed for designing a small dual-band slot antenna using capacitor loading. A capacitor is loaded at the right end of a slot antenna to form a parallel resonance using inductance generated by the slot end. As the impedance of the parallel resonator becomes capacitive at a frequency higher than the resonance, the slot antenna resonates at less than a quarter wavelength. To match input impedance in dual-band, a coupled feed is placed near the capacitor and a structure for frequency tuning is also proposed. The antenna is simulated and fabricated to resonate at the 2.4 and 5.8 GHz bands with slot size of 0.16λ × 0.05λ. The bandwidth of the antenna is 90 MHz at 2.4 GHz and 760 MHz at 5.8 GHz. By measuring radiation patterns, the efficiency is no less than 70% at 2.4 GHz and 60% at 5.8 GHz band.

KEYWORDS
capacitor, loading, parallel resonator, slot antennas

1 | INTRODUCTION
A slot antenna is made by etching a slot in a metal surface and its resonant frequency depends on the size and shape of the slot. As the parts or materials attached to the metal surface have no significant effect on the performance of the antenna, it is a preferred type of antenna for installation in an environment surrounded by metallic materials. Because the slot structure has an advantage in accommodating lumped elements such as inductors or capacitors, it is useful as a tunable antenna. In practice, varactor diodes, pin diodes, stubs and liquid metal Galinstan have been embedded in slot antennas in designing tunable antennas.1–4 As a slot antenna uses the ground plane, its performance could be enhanced by integration with conventional antennas such as monopole or inverted F antennas.5–7 A slot antenna can be used to advantage in designing the antenna for a portable device which has a metal case or metal frame.8,9 But as the slot antenna has a structure with half-wavelength resonance, it is difficult to reduce the antenna size10–14 and the slot size is fundamentally dependent on the surrounding equipment which creates difficulties with antenna design. A slot antenna with open end is proposed to reduce the antenna size.15,16 However, in actual practice, this requires cutting the metal frame, which places constraints on the design options.

This letter proposes a technique to reduce slot size of a mobile device antenna using capacitor loading along with a technique to utilize a dual-band design.

2 | LOADING EFFECTS OF THE SLOT ANTENNA
Transmission line models for a conventional slot antenna and the proposed antenna are illustrated in Figure 1. A conventional slot antenna with a half wavelength resonance can be modeled incorporating a transmission line with shorts on the left and right. When connecting the capacitor to the short at either end of the slot antenna, parallel resonance is formed..