Low RCS Transmitarray Using Phase Controllabe Rasorber

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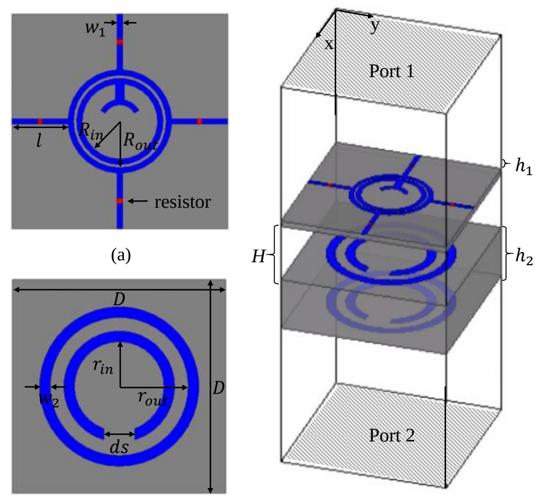
***Abstract*—A phase controllable rasorber, also named as phase controllable absorptive frequency-selective transmission (AFST) surface, is developed in this paper. It is composed of asymmetrical resonators with lumped resistors, achieving an absorption-transmission-absorption response. Compared with other reported rasorbers, the proposed one has an additional feature that is to realize a 1-bit phase change of its element within the transmission band by rotating the element by 90°. A low radar cross section (RCS) transmitarray is designed at 12.5 GHz with a peak realized gain of 24.4 dBi using the developed elements. The 10 dB RCS reduction bandwidths are 18% and 14% for the lower and upper absorption bands, respectively.**

Keywords—transmitarray; rasorber; absorptive frequency-selective transmission (AFST) surface; radar cross section (RCS)

I. Introduction

High-gain antennas have wide applications for space and terrestrial wireless systems due to their merits of increasing the signal to noise ratio for long-distance communications. To increase the gain of an antenna, a straightforward solution is to enlarge the antenna radiation aperture. However, the scattering area of the antenna will also increase, resulting in an elevated radar cross section (RCS) which is adverse for low-observable designs. Thus, there is a tradeoff between high-gain and low-RCS properties for high-gain antennas. Recently, many high-gain low-RCS antennas are reported based on artificial magnetic conductors (AMCs) [1-2], superstrate layers [3-5], or metasurface [6-7]. Since reflectarrays and transmitarrays that employ spatial feedings are competitive high-gain antenna candidates [8], several efforts on low RCS reflectarrays are demonstrated [9].

In this paper, a phase controllable rasorber element is developed for a low RCS transmitarray for the first time. The element can achieve an absorption-transmission-absorption response and a 1-bit phase change in the transmission band. It should be noted that most of the other reported rasorber elements cannot change their transmission phases in the transmission band, focusing on periodic surface designs. However, for transmitarrays, the elements need to provide a digital or continuous phase change to provide required phase compensation. Actually, it is very challenging to manipulate the phase response of the rasorber elements as the phase response is usually related to the element's transmission and absorption



(b) (c)

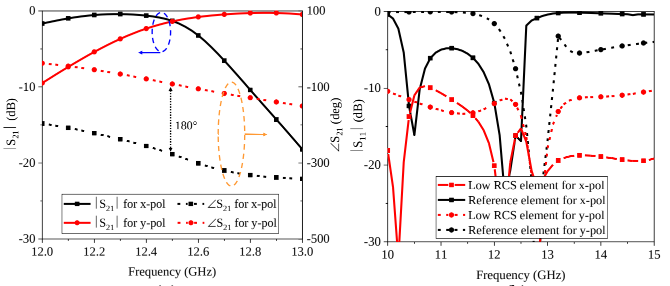
Fig. 1. Configuration of the phase controllable rasorber element (Blue part is the metal). (a) Top side of the first substrate. (b) Top or bottom side of the second substrate. (c) HFSS model of the element. (R_{in} = 2.15 mm, R_{out} = 2.65 mm, r_{in} = 2.58 mm, r_{out} = 3.97 mm, w_1 = 0.31 mm, w_2 = 0.6 mm, l = 3.18 mm, ds = 1.79 mm, D = 12.26 mm, H = 5 mm, h_1 = 0.5 mm, h_2 = 4.5 mm)

performance. In this paper, we successfully address this challenge by proposing a new rasorber element. By utilizing this phase controllable rasorber element, a low RCS transmitarray is designed at 12.5 GHz. Significant RCS reductions are achieved in the two absorption bands which are at two sides of the transmission band.

II. Phase Controllable Rasorber Element

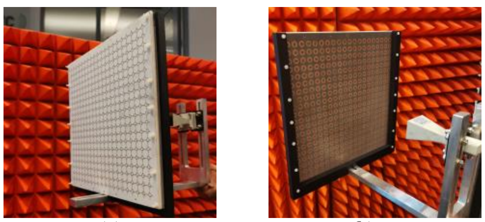
As shown in Fig.1, the proposed phase controllable rasorber element is composed of two substrates which are separated by an air spacer. As seen from Fig.1(a), the top side of the first substrate consists of a dual circular ring and four metallic striplines embedded by four lumped resistors. The resistors are 200 Ω. The inner circular ring is also connected with an arched metal strip. The top and bottom sides of the second substrate are the same, which are composed of a dual circular ring with a split on the inner circular ring as shown in Fig. 1(b).

The frequency response of the proposed phase controllable rasorber element is analyzed in a periodic boundary condition



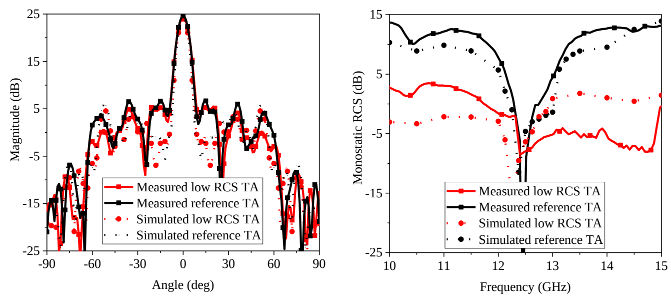
(a) (b)

Fig. 2. (a) Simulated transmission phases and magnitudes of proposed phase controllable rasorber element. (b) Simulated input reflection coefficients of proposed and reference elements.



(a) (b)

Fig. 3. Photograph of the fabricated low RCS transmitarray. (a) Front side. (b) Back side.



(a) (b)

Fig. 4. Measured and simulated results of low RCS transmitarray and reference transmitarray. (a) Patterns at 12.5 GHz. (b) Monostatic RCSs under nornal impinging waves.

by EM simulation software HFSS for both x- and y-polarizations as shown in Fig. 1(c). It is seen from Fig. 1 that the resonant length of the element for x-polarization is longer than that for y-polarization because of the arched strip on the top side of the first substrate and the splits on both sides of the second substrate. Therefore, the resonance frequency of the element for x-polarization is lower than that for y-polarization. Based on the resonance frequency difference between x- and y-polarizations, a 180° phase change between the two polarizations and an overlapped transmission band from 12.35 GHz to 12.60 GHz with an insertion loss less than 3 dB can be achieved as shown in Fig. 2(a). Therefore, a 1-bit phase change can be realized by rotating the proposed element by 90°, which can be used to achieve the phase compensation for a transmitarray with a given polarization (x- or y-polarization). To realize RCS reduction of a transmitarray, the amount of the incidence waves reflected by the proposed element should be very small for both x- and y-polarizations. As seen from Fig. 2(b), the input reflection coefficients of proposed element (red curves) are lower than -10 dB from 10 GHz to 15 GHz for dual polarizations. For comparison, a reference element is also simulated (black curves), with resistors replaced by short striplines. Its $|S_{11}|$ is greater than -10 dB across the band.

III. LOW RCS TRANSMITARRAY

A low RCS transmitarray is designed at 12.5 GHz by utilizing the developed rasorber elements, as shown in Fig. 3. A reference transmitarray is also designed for comparison by using the reference elements. As shown in Fig. 4(a), the measured peak realized gains of the low RCS transmitarray and the reference one are 24.4 dBi and 24.5 dBi at 12.5 GHz, respectively. Under normal impinging waves, the measured monostatic RCS shows more than 10 dB reduction from 10 to 12 GHz (18 %) and from 13 to 15 GHz (14 %), as shown in Fig. 4(b). More details on the results, e.g., the RCSs of the array under oblique impinging waves and the realized gains versus frequency, will be presented in the conference.

IV. CONCLUSIONS

A phase controllable rasorber element is proposed to obtain an absorption-transmission-absorption response. It can also achieve a 1-bit phase change within the transmission band by rotating the element. A low RCS transmitarray is designed by utilizing the proposed element, which has a comparable realized gain with the reference transmitarray. Meanwhile, significant RCS reductions have been achieved at two absorption bands.

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