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Characterizing transmitting phased array antenna elements using a metasurface and IR camera

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Summary

This paper presents a novel method to characterize transmitting phased array antenna elements using metasurfaces and an IR camera. Modern phased array antennas for SatCom-applications are often manufactured using PCB technology where the antenna elements are integrated with the electronics, controlling the phase and amplitudes of the elements. In production, it is difficult to detect and identify possible manufacturing errors using radiation pattern measurements. The power transmitted from individual elements can be monitored by placing the metasurface in front of the antenna element. The metasurface absorbs the incoming radiation and localizes the generated heat to small regions consisting of lossy elements. The generated heat is proportional to the power density and is detected by an IR camera. In combination with thermal isolation between elements, this allows for a measurement system measuring the power levels of radiated devices without any direct connection between the antenna under test and the measurement equipment. The method is demonstrated on a 16 x 16 element phased array antenna intended for transmission (Tx) in the Ka-band. The array antenna is a prototype with the ability to individual element control of both phase and amplitude. Different amplitude patterns and signal levels have been measured. Amplitude variations down to 0.5 dB were shown to be detected. The method can be further developed and optimized for future production control of (transmitting) phased array antennas where amplitude control of elements is important.

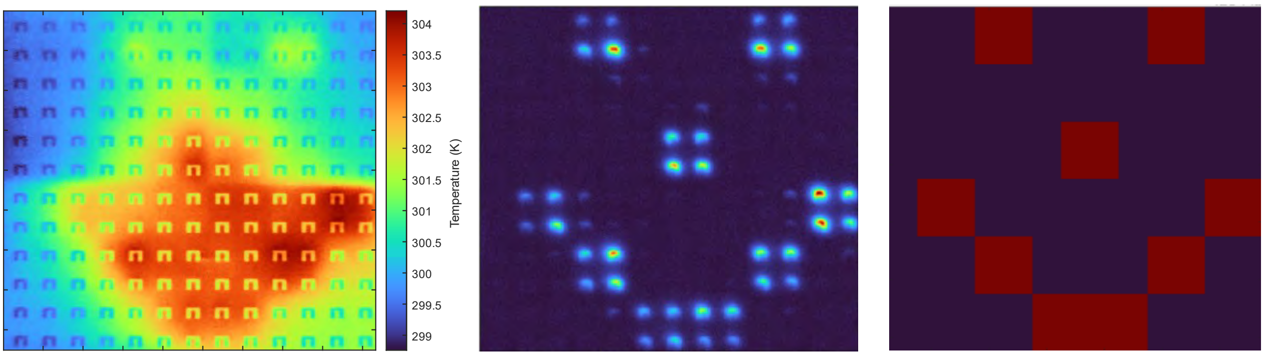
1. Introduction

There is an increased demand for phased array antennas in Satellite Communication (SatCom), 5G, and radar applications. Modern manufacturing technology facilitates the integration of array elements and electronic control systems on PCBs. For SatCom applications, it is necessary to control both element phase and amplitude (for polarization and tapering control). Due to the integration, it can be difficult to detect any manufacturing or programming errors in the production line. Deviations from expected performance in radiation pattern measurements are difficult to trace down to elements or components in the array antenna. A novel approach for transmitting antenna arrays is to use the detection of infrared radiation as a result of the heating of small sub-wavelength elements on a metasurface positioned in front of the antenna array. Each metasurface element can ideally be located above each array element, resulting in a measurement of each antenna element in the near field.

The antenna used in this study is a prototype for the “RESA-S Ka”, fully integrated phased array flat panel antenna terminal suitable for Satcom - “On-The-Move” over LEO/MEO/GEO constellations (Low Earth Orbit, Medium Earth Orbit, Geostationary Orbit) [1].

2. Results

The measurements were performed in a semi-anechoic chamber at ReQuTech in Linköping. The 16 x 16 element antenna array was mounted on a turntable (fixed in this case). This Tx antenna can operate in the Ka-band (27.5 GHz - 31 GHz). The measurements were performed at single frequencies, 27.6 GHz using a signal generator coupled to the array antenna. A pulse generator was used to periodically modulate the signal, transmit for 2 seconds and rest for 3 seconds. An antenna control unit is connected to the array antenna where different amplitudes of the elements can be controlled by a graphical user interface. The metasurface was placed close to the array (2-5 mm away). Measurements were conducted in real-time where it could be observed which antennas were radiating. An example measurement is seen in Fig. 1, where a randomly picked frame from the IR camera of the measurement is shown (a) with a temperature in Kelvin. The region is approximately 7 x 7 cm^2. During a measurement, the thermal processes can be seen to influence. There are temperature drifts, global temperature changes, and strong background temperature, which is the reason for the large temperature visible in Fig. 1 (a). However, the measured data can be processed to account for these apparent problems in the time domain [2] and in the frequency domain. In Fig. 1 (b) an image of the heating is shown based on the amplitude of the 0.2 Hz component of the frequency domain data. The active antennas can alternatively be displayed through a threshold image, either on or off, Fig. 1 (c). This provides a rapid, (5-10 second), measurement of fault detection of the antenna array. Several different patterns were measured.



(a) (b) (c)

Figure 1. a) Image of a single IR-camera frame. b) The amplitude of the 0.2 Hz fourier component based on a measurement of 10 periods (50 seconds). c) Image displaying the radiating elements either on or off.

The metasurface was originally designed for a different periodic spacing than the measured antenna. This causes some misalignment of the image and results in elements toward the edge of the image being placed in between radiating patches.

The array antenna elements consist of circular patch elements that can transmit either right-hand or left-hand circular polarization. The orientation of the linearly polarized elements on the metasurface is therefore not important in this case. Different amplitude patterns were tested where also the amplitude level was varied. It was found that amplitude steps of 0.5dB were possible to detect. The results and further details of these measurements with images and a movie demonstrating the concept will be presented at the conference.

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References

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