Metamaterial inspired microwave focal plane array

W. Xu[1], D. Shrekenhamer[2], S. Venkatesh[3], D. Schurig[3], S. Sonkusale[1] and W. J. Padilla[2]

[1]Department of Electrical and Computer Engineering, Tufts University, MA 02155, USA
Fax: + 1-617-627-0909; email: wangren.xu@tufts.edu
[2]Department of Physics, Boston College, Chestnut Hill, MA 02467, USA
Fax: + 1-617-552-8478; email: willie.padilla@bc.edu
[3]Department of Electrical & Computer Engineering, University of Utah, Salt Lake City, UT 84112, USA
Fax: + 1- 801-581-5281; email: david.schurig@utah.edu

Abstract

We present a metamaterial inspired detector array for room-temperature detection of gigahertz radiation. The system is implemented on printed circuit board and we characterize the sensitivity and radiation pattern. The metamaterial unit cell is loaded by an impedance matching circuit to tune the resonance strength and frequency of the metamaterial to account for variations in fabrication. The proposed sub-wavelength pixel shows enhanced detection sensitivity of -61dBm.

1. Introduction

The electrically coupled LC resonator (ELC) has been successfully employed to implement a perfect metamaterial absorber at microwave frequency [1][2]. In this absorber, the majority of incident electromagnetic energy is focused in the metamaterial gap and converted to dielectric and / or ohmic loss. At frequencies less than tens of THz, dielectric loss is dominant over ohmic if the substrate is lossy. Here, however, we utilize the metamaterial perfect absorber to guide electromagnetic radiation to a receiver detection circuit and thus measure incident microwave power.

In this paper, we present details of the architecture and characterize the metamaterial inspired microwave power receiver system. All system components have been integrated in a single printed circuit board (PCB). Each unit cell of the metamaterial array is connected to a receiver chain with on board *vias*, which guide the absorbed electromagnetic power into the microwave receiver.

2. System architecture and implementation

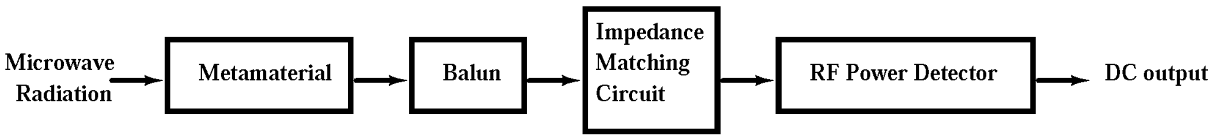

Fig. 1: System architecture of metamaterial inspired microwave power receiver.

The system architecture of a metamaterial inspired microwave power receiver is shown in Fig. 1. We fashioned an 11 by 11 array of ELCs on a PCB, in which each unit cell is followed by a balun, impedance matching circuit and a microwave power detector. The entire system has been implemented on a Rogers PCB in a four layer process. The top layer is the metamaterial array, followed by a ground plane, power routing plane, and the circuit plane makes up the bottom layer. Photos of the fabricated system are shown in Fig. 2 (a)-(d). Dimensions of a single metamaterial unit cell, and the opening of the ground plane, are shown in Fig. 2 (e).

Via holes connect the two sides of the ELC resonator's capacitive gap to a balun on the circuit layer. A cut-through in the ground plane permitted *vias* to connect through to the circuit layer and was designed

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to minimize parasitic capacitance between the ground plane and ELC. The balun is used to convert the balanced microwave signal at the gap of the metamaterial to an unbalanced signal, which can be

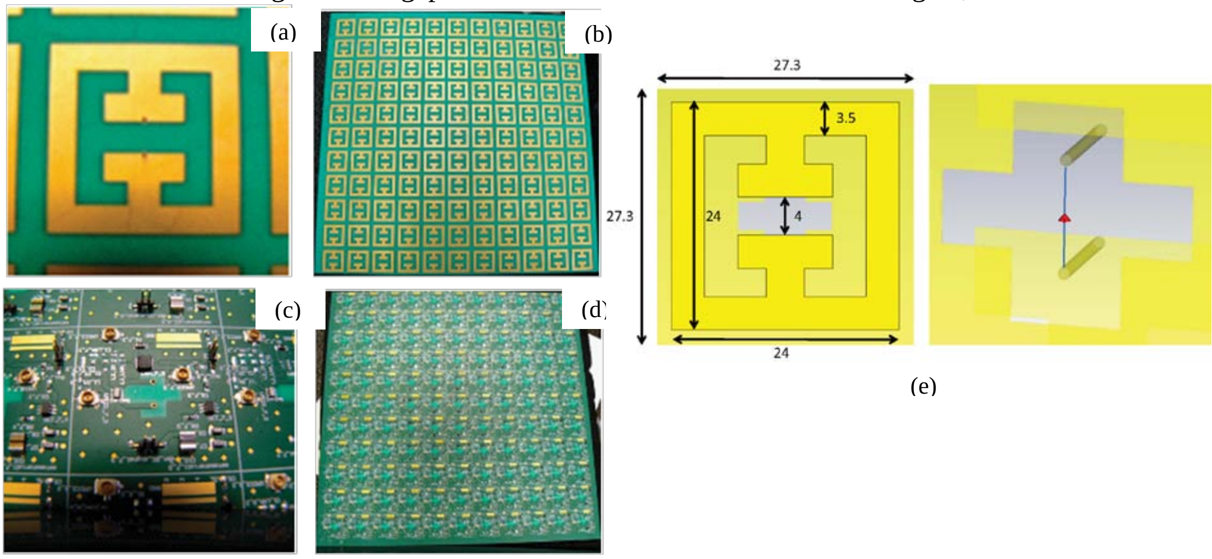

Fig. 2: (a) One unit cell of metamaterial on the top layer of PCB (b) The whole metamaterial array (c) The microwave power receiver circuit underneath one metamaterial unit cell (d) The whole array of microwave power receiver circuit (e)The dimension of one metamaterial unit cell with vias, unit in mm.

fed into the impedance matching circuit and following stages. The impedance matching circuit compensates for ELC resonator and other component variances in the fabrication process, and tunes the resonance frequency and strength of metamaterial. The impedance matching circuit is shown in Fig 3. The microwave power detector, which converts the power into a DC voltage, is the LT5534 made by Linear Technology.

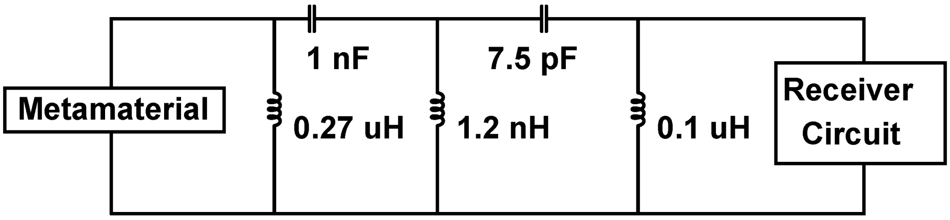

Fig. 3: The impedance matching circuit is composed of 5 surface mount inductors and capacitors.

3. Measurement setup and result

Free space measurements were performed within an anechoic chamber. Fig. 4 shows a photo of the experimental setup and measurement results. An HP 8510B vector network analyzer (VNA) was used to measure the transmission and reflection coefficients of the metamaterial array. A double ridge guide horn antenna (700MHz – 18GHz range) was used as a transmitter which was connected to Port 1 of the VNA with an input power level of -3dBm. Port 3 of the VNA was connected to the impedance matching circuit output of a single metamaterial (MM) unit cell located at the centre of the metamaterial inspired focal plane array (MM-FPA). Only this centre pixel of the MM-FPA was measured. The MM-FPA was located in the far field of the horn at a distance of about 1.67 m. In Fig. 4 (b), the best detection frequency is located at 2.495 GHz, where impedance of metamaterial is matched to 50 Ohm. The off-angle performance of the MM-FPA at 2.5 GHz was measured (See Fig. 4 (c)) and the radiation pattern is measured for both the electric field vector perpendicular and parallel to the floor of the chamber, we have also rotated the sample in both cases to measure the transverse electric (TE) and magnetic (TM) field orientations. The measurement results indicate that our metamaterial is a wide angle antenna and has the maximum gain at 0, 45 and 315 degree. We also show that the correct TE polarization, which is represented by black curve in the figure and marked as Co-polarization, is required to receive the highest transmitted signal. In the sensitivity test, the frequency of the synthesizer,

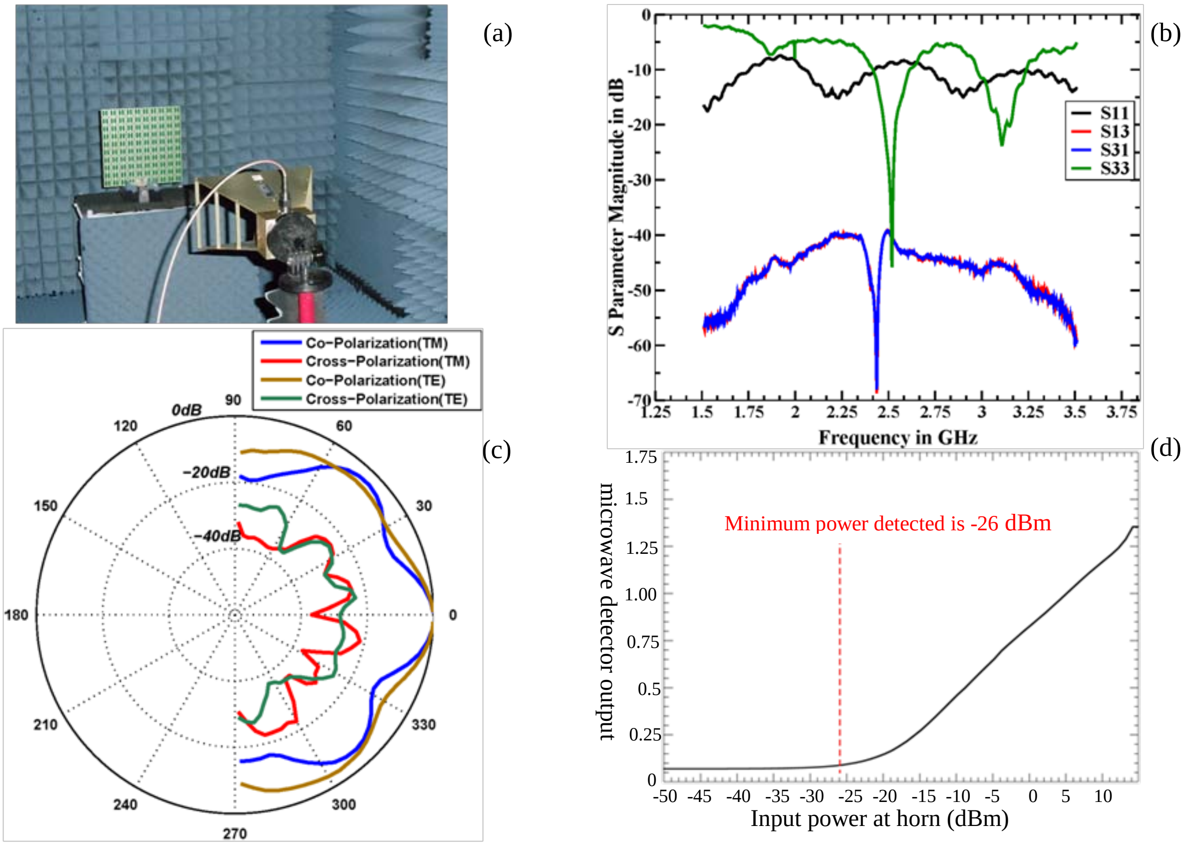

Fig. 4: (a) Measurement setup (b) S_{11} is the measured reflection coefficient of horn antenna, S_{33} is the measured reflection coefficient at impedance matching circuit output and S_{31}/S_{13} is the measured transmission coefficient (c) normalized radiation pattern, co-polarization means the electrical field is perpendicular to the gap plates of the metamaterial unit cell, while cross-polarization means that the electrical field is in parallel to the gap plates (d) measured sensitivity of a single metamaterial pixel

which feeds the horn, is fixed at 2.495 GHz. The power level fed to the horn was swept from -50dBm to +20dBm and the corresponding DC voltage from the microwave detector was recorded, see Fig. 4 (d). Our MM-FPA is sensitive to a power level of -26 dBm at the horn end at 2.495 GHz. Taking the cable loss and free space loss into account, this indicates that the sensitivity of the centre pixel detector of MM-FPA is -61 dBm.

4. Conclusion

The measured pixel of our metamaterial inspired microwave detector array was proven to have high sensitivity, good frequency selectivity and wide angle performance. We are continuing our work to make the entire 11 by 11 metamaterial array work as a focal plane array image sensor or microwave source localization detector. This metamaterial inspired, single board design could be scaled for higher frequency application.

5. References

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