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# WIDEBAND AND COMPACT MICROWAVE FRONT-END CIRCUIT FOR ADAPTIVE PLASTIC LANDMINE IMAGING ARRAYS

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## 1 Introduction

The ground penetrating radars (GPRs) are widely applied to underground pipe detection, ruin investigation, ground water mapping, and so on [1], [2]. The landmine detection is one of the promising applications because the GPRs are expected to detect even nonmetallic mines [3], [4], [5]. The antipersonnel plastic landmine detection is, however, a hard problem since the mine has a small size, a low reflectance, and a high land-surface reflectance in particular when they are buried shallowly. The demining should also be automated for the dangerousness of the process and the shortage of experts.

Previously we proposed a multiple-frequency interferometric radar imaging system using complex-valued neural networks [6] for the plastic landmine detection. The system measures both the amplitude and phase information at multiple frequency points. It was demonstrated successfully that a complex-valued self-organization map (C-SOM) module processes adaptively the obtained images to visualize the plastic landmines [7].

The system has further to satisfy various requirements. One is to realize a handset that is simple, small, lightweight and robust. Another is to obtain a wide bandwidth. Our system measures the reflection as a set of complex-amplitude images two-dimensionally. Therefore, it is desired to develop a compact, phase-sensitive and arrayed front-end consisting of wideband antennas and mixers.

This paper reports that we have designed and fabricated a microwave front-end unit and obtained a sufficient performance. The scanning bandwidth of the continuous-wave (CW) microwave should be wide enough to realize a high spatial resolution. On the other hand, the center frequency be desirably lower for a larger penetration depth. The front-end unit realizes homodyne detection with a center frequency of about 8GHz and a bandwidth of about 4GHz-12GHz. Experiments demonstrate that, though the amplitude fluctuation is observed, the unit has a good performance sufficiently to realize a plastic landmine imaging system by using the adaptive complex-valued neural processing by using the C-SOM.

## 2 Design and fabrication of the front-end

Figure 1(a) is a conceptual illustration of the handset and the total system. The signal processing by the complex-valued neural network is performed ether at the handset or on a distant personal computer (PC) with a wireless communication. Figure 1(b) shows the basic construction of the handset where a radio frequency (RF) wave is divided and fed to arrayed front-end units. We assume a single-phase RF feeding to realize a massively parallel front-end array.

Figure 1(c) shows the front-end circuit. Generally speaking, we can prepare two orthogonal local oscillators (LO) to realize homodyne detection. However, to simplify the massively parallel

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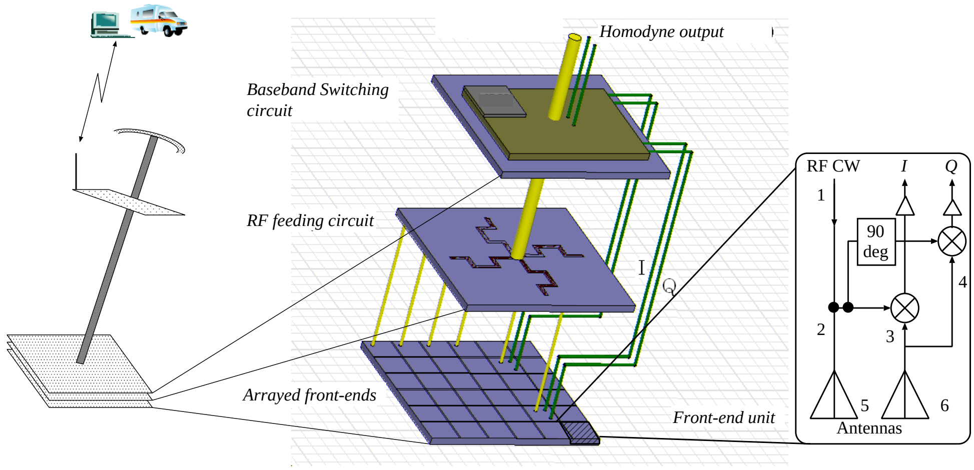


(a) (b) (c)

Figure 1: Schematic construction of the plastic landmine imaging system: (a)total system, (b)handset and (c)front-end unit including antennas and homodyne circuit.

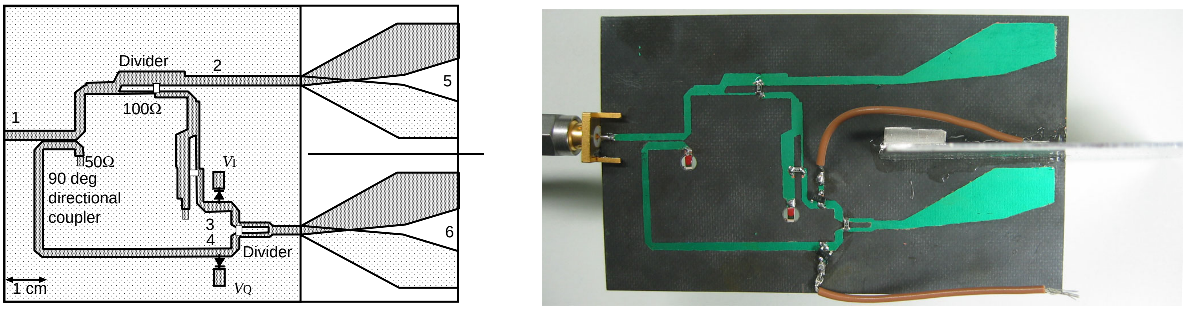
divisions, we generate an orthogonal LO from a single phase LO at the front-end unit by using a wide bandwidth 90-deg directional coupler. This paper reports the design, fabrication and experimental results of the front-end unit.

Figure 2(a) presents the front-end circuit pattern. Port 1 is the input terminal. The input RF wave is divided by a wideband 90-deg directional coupler. The coupler is designed with a center frequency of 8GHz and its length is quarter wavelength. The split RF is guided to Port 4 as the quadrature-phase LO.

The straight RF wave is again divided by an unequal split Wilkinson coupler [8]. Port 2 wave is lead to Port 5, a transmitting antenna, while the other is used as the in-phase LO at Port 3. Resistors are inserted at the dividers for reduction of reflection effects. In this paper, the division power ratio is determined as Port 2 : Port 3 : Port 4 = 12 : 1 : 1.

Port 5 is the transmitting antenna. To realize a wide transmission frequency bandwidth, we fabricate a linearly tapered slot antenna (LTSA). Port 6 is an identical receiving antenna. We also put an aluminum plate to reduce the direct coupling between the transmitter and the receiver.

We substitute simple envelope detectors using diodes for a little more complex mixing circuit. Though an offset voltage is generated at the envelope detector, it is processed adaptively in the following neural network.



(a) (b)

Figure 2: (a)Antennas and homodyne circuit pattern and (b)photograph of fabricated circuit.

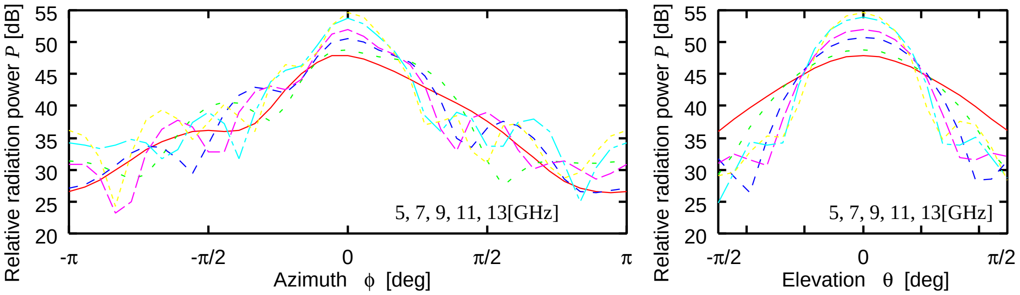
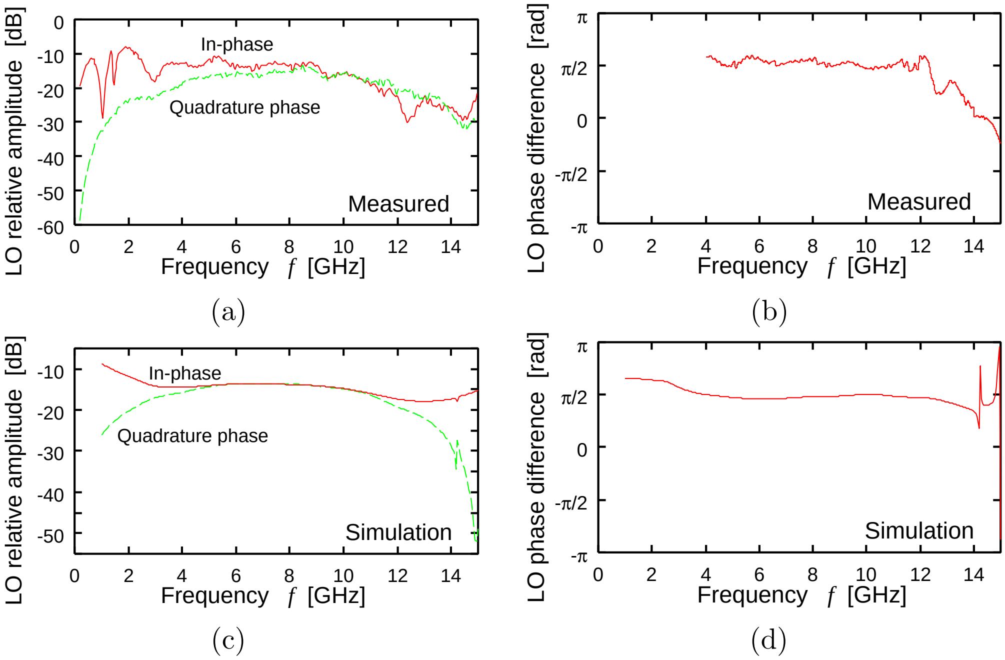


Figure 3: Simulated near field patterns.



(a)

(b)

(c)

(d)

Figure 4: Measured (a)amplitudes and (b)phase difference of LOs at the mixers, and (c) and (d)those of simulation.

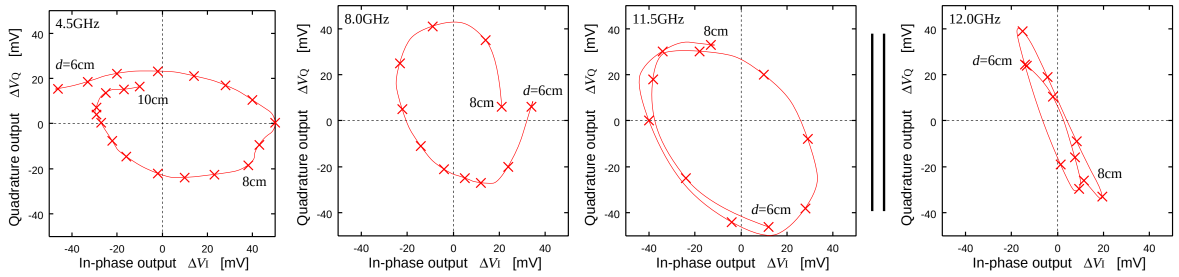
Figure 2(b) is the photograph of the fabricated front-end unit. The board is Rogers RT/duroid 5880 (relative permittivity 2.2, thickness 0.508mm). Chip resistors are 50Ω for termination and 100Ω for reflection effect reduction.

## 3 Experimental and simulation results

Figure 3 shows the radiation patterns calculated for the antenna unit. Azimuth stands for the angle in the board plane, while elevation in an orthogonal plane. The pattern is smooth and has no peculiarities.

Figure 4 shows the LO characteristics against frequency. Experimental measurement of amplitude and phase difference at Ports 3 and 4 is given in Fig.4(a) and (b), respectively. We obtain orthogonal and almost equally leveled LO over the range of 4GHz – 12GHz. The maximum power deviation is about 6dB, while the maximum phase difference fluctuation is about 10deg. They are small enough to be eliminated by the following adaptive neural processing. Figure 4(c) and (d) presents the counterparts obtained by simulation. The simulation results are near to the experimental ones.

Figure 5 shows the trace of the homodyne outputs when we locate an aluminum reflector in front of the front-end unit and move it with 2mm interval. The offset voltage is excluded. We find that the output phase rotates smoothly. When the frequency becomes higher, i.e., (a)4.5GHz, (b)8GHz and (c)11.5GHz, the rotation velocity increases appropriately. Though the trace is elliptic because of the amplitude dependence on frequency, the incompleteness can be compensated through the C-SOM adaptive processing. In the marginal regions of the operation frequency, the trace becomes sometimes further deformed as shown in Fig.5(d) measured at 12GHz.



(a) (b) (c) (d)

Figure 5: Homodyne output traces when a reflector is located 6cm distant from the antennas and moved with 2mm interval: (a)4.5GHz, (b)8GHz, (c)11.5GHz and (d)12GHz.

# 4 Conclusion

We have designed and fabricated a compact microwave front-end unit for plastic landmine imaging based on complex-valued neural networks. The front-end realizes homodyne detection of reflected microwave with a wide scanning frequency range of 4GHz - 12GHz with a low center frequency of 8GHz, which are desirable for shallowly buried plastic landmine imaging.

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