

Self-Calibration for Arrayed Penetrating Radar

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Abstract— This paper describes a calibration method for arrayed radar. By using an additional pair of transmit/receive ports, on-line calibration for arrayed radar is possible.

Keywords— calibration, arrayed radar

I. INTRODUCTION

To rescue the victims under the rubble is gradually taking attention to radar researchers [1,2,3]. Especially to enhance detection performance multiple transmitting and receiving antennas are used in [3]. To detect motion of victims beneath rubble, the arrayed radar gives better performance than a single radar. One of disadvantage of the arrayed radar is that the system calibration with multiple paths is difficult. System varies with operating environment such as temperature, humidity, electricity condition, and so on. Arrayed radar has multiple antenna paths and ports in general. Multiple components lies on each path, of which characteristics are varies according to the environment condition. To achieve good radar response, every path should be correctly calibrated. During the calibration, antennas should be disconnected from the ports and connected to a special calibration device. It is uneasy to perform the operation for each path frequently, which makes it impossible to perform the on-line calibration for the arrayed radar. In this paper a self-calibration method for arrayed radar is described. The presented method requires no inconvenient connection and disconnection operations. Instead, it requires a specific calibration path. Experimental results of the presented method are also provided, in which four paths can be conveniently calibrated without no uneasy operation.

II. SYSTEM CALIBRATION

A system is generally represented by its input and output as shown in Figure 1.

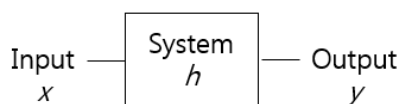


Figure 1. System representation

Its response is written as

$$H(f) = \frac{y(f)}{x(f)},$$

where f denotes frequency. In case of measurement devices, their system response should be calibrated in order to observe the pure characteristics of a Device-Under-Test(DUT).

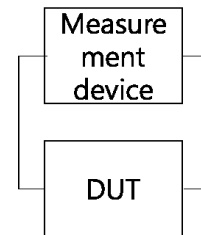


Figure 2. Measurement device and DUT

The arrayed radar now discussed in this paper has the following system structure as depicted in Figure 3. For the user, the measurement device consists of the transceiver, TXP, RXP, the path selector, and Antenna-Module(AM)s. The Pandora box is DUT. The characteristics of AM is almost unchanged, thus its characteristics usually identified once in an anechoic chamber. The rest components of the measurement device are vulnerable to the environmental status. For example, the system response varies every power on, cable connection status, temperature, humidity, and so on.

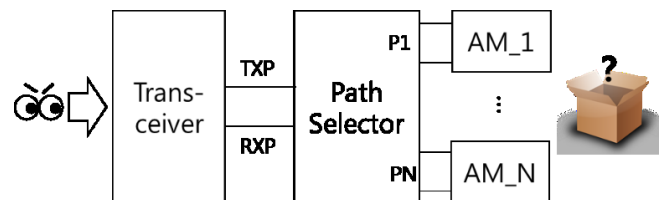


Figure 3. Arrayed Radar System

The arrayed radar has N-paths as in Figure 3. To calibrate them, calibration kits are necessary to be connected to them as shown in Figure 4. It is inconvenient to calibrate the system after every power on. Furthermore, it is impossible to sense the calibration status while the system is under operation. Therefore, a method is required to calibrate the system conveniently and sense the calibration status contiguously.

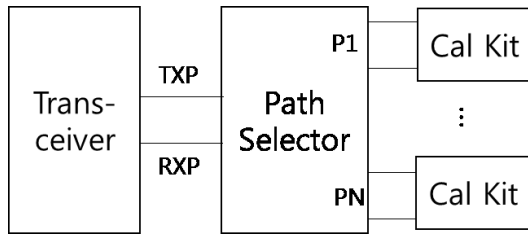


Figure 4. System calibration

III. SELF-CALIBRATION

Self-calibration requires an additional specific path, which is called calibration path. The N arrayed radar system architecture is depicted in Figure 5.

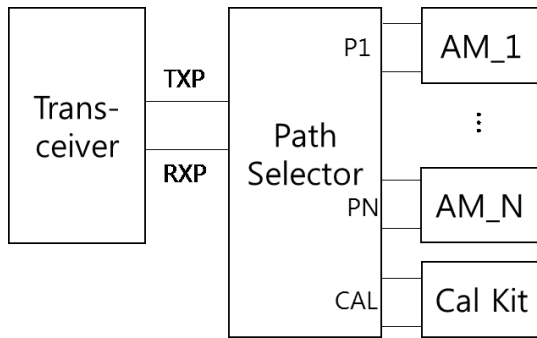


Figure 5. Self-calibration system

Self-calibration consists of two steps. The first step is preparation step which is required just once. The second step is main step which is performed frequently while the system is being operated. Table 1 is the procedure of the preparation step, and Figure 6 is the system setup for the preparation step. First of all, the calibration kit is connected to the calibration path, and other paths are terminated. At the x and y ports in the transceiver, the inverse of the system response for the calibration path, Q_{CAL} which is written in (1), is measured.

$$Q_{CAL}(f) = \frac{X(f)}{Y(f)}. \quad (1)$$

Then, the inverse response of the other paths, $Q_1, \dots, Q_N$, are measured through the same manner as the calibration path. R_n , which is used for the correction term in the main step, is written as

$$R_n(f) = \frac{Q_n(f)}{Q_{CAL}(f)},$$

where $n=1, \dots, N$. Note that the R_n are constant value because R_n can be written as

$$R_n = \frac{Q_n}{Q_{CAL}} = \frac{H_{CAL} H_S H_{CC}}{H_n H_S H_{nC}} = \frac{H_{CC}}{H_{nC}}, \quad (2)$$

where H_{CC} is the constant response of the calibration path, H_{nC} is the time invariant response of the n -th path and H_S is

the time variant response of the system. Thus, R_n is constant because H_{CC} and H_{nC} are constant. Note that we assumed that the physical structures of the paths are symmetrical each other. The purpose of the preparation step is to obtain the R_n for $n=1, \dots, N$. This step is required only once when the system is initially set up.

TABLE 1. PREPARATION STEP

1. Get Q_{CAL}
2. Get $Q_1, Q_2, \dots, Q_N$
3. Calculate $R_1, R_2, \dots, R_N$

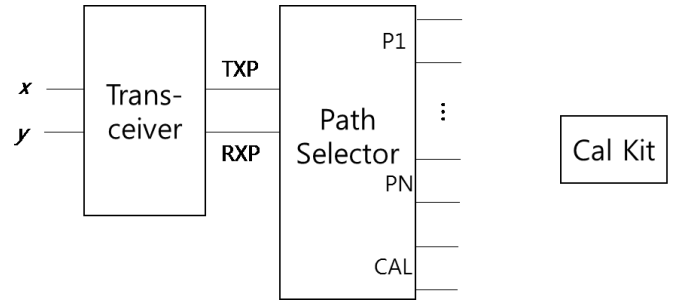


Figure 6. Preparation step

Table 2 is the procedure of the main step. The system setup is shown in Figure 5. This step is required at every power on time. It can be performed when the temperature is changed, or when a physical shock or vibration is sensed. It can be also performed periodically in order for the system to be stably calibrated. Firstly, the inverse system response of the calibration path, $\hat{Q}_{CAL}$, are measured. Then the inverse system response of n -th path, $\hat{Q}_n$, can be obtained as follows,

$$\hat{Q}_n(f) = \hat{Q}_{CAL}(f) \cdot R_n. \quad (3)$$

(3) can be written as

$$\hat{Q}_{CAL}(f) \cdot R_n = \frac{1}{H_S H_{CC} H_{nC}} = \frac{1}{H_S H_{nC}} = \hat{Q}_n, \quad (4)$$

thus it can be said that (3) is the newest inverse system response of n -th path. By using Table 2, we can easily update the inverse system response of the n -th path as the system setup in Figure 5.

TABLE 2. MAIN STEP

1. Get $\hat{Q}_{CAL}$
2. Get $\hat{Q}_1, \hat{Q}_2, \dots, \hat{Q}_N$

IV. EXPERIMENTAL RESULTS

In this experiment, a four-path radar system depicted in Figure 7 is used. System response of the path 1 is depicted in Figure 8, where the path is uncalibrated. Through this system,

the path response of a radar pulse is distorted as shown in Figure 9. Using the self-calibration in Section III, the calibrated system spectrum and phase response is shown in Figure 10. Note that the spike-like signals in the figure resulted from the system internal noise. The self-calibrated path response is shown in in Figure 11. The other paths have their system spectrum and phase response as in Figure 12, where their characteristics are slightly different and varies as the system status. All the paths can be successfully self-calibrated as shown in Figure 13.

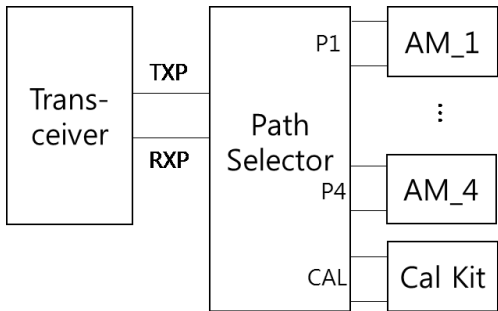


Figure 7. Four-path radar system

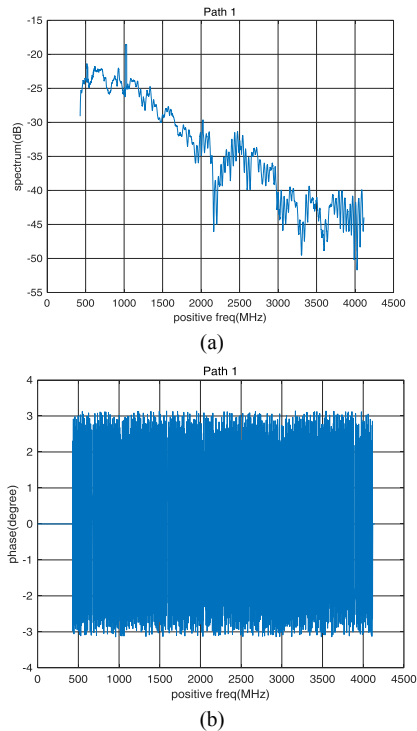


Figure 8. System (a) spectrum and (b) phase response of path 1

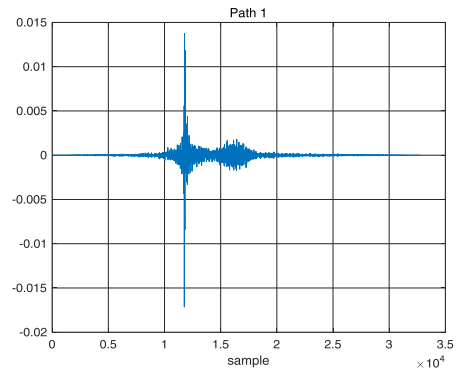


Figure 9. Uncalibrated path response

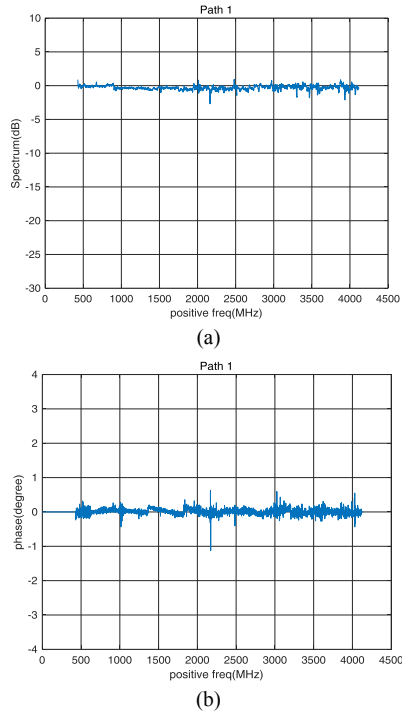


Figure 10. Self-calibrated system (a) spectrum and (b) phase response

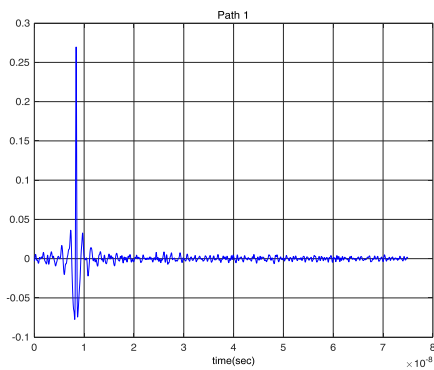


Figure 11. Self-calibrated path response

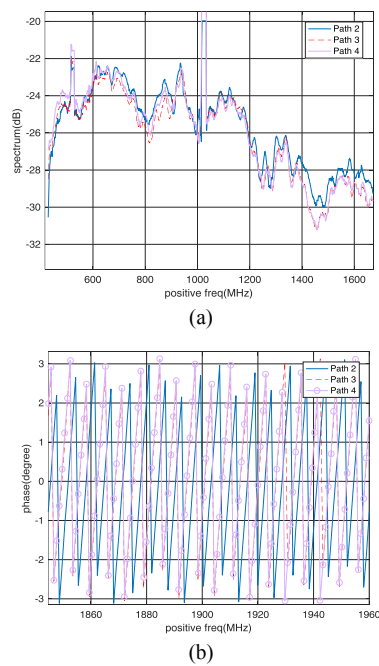


Figure 12. Uncalibrated system (a) spectrum and (b) phase response of path 2, 3, and 4

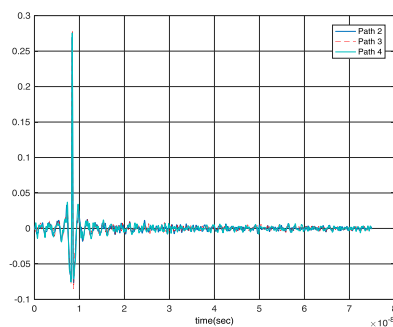


Figure 13. Self-calibrated path response of path 2, 3, and 4

V. CONCLUSIONS

In this paper, a self-calibration method is proposed. It makes it possible for the arrayed radar to calibrate itself by on-line manner. Future work is to enhance the calibration performance while the system internal noise degrades the calibration result.

ACKNOWLEDGMENT

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