Radar Modeling Experiment Using Vector Network Analyzer

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***Abstract*—Radar modeling is an important method in the radar experiment. Vector Network Analyzer (VNA) as equipment that used for measuring the Scattering parameter of radio frequency (RF) Circuit can be applied to develop a radar model that is used in a certain radar experiment. The basic concept of radar modeling using VNA is discussed in this paper. The radar modeling sample and its result are also provided. Radar modeling using VNA provides flexibility in developing a radar experiment for many radar topologies and detection cases. The VNA-based radar model provides a good representation of the radar system that is studied.**

***Keywords*—Radar, Modeling, Vector Network Analyzer.**

I. Introduction

Radar modeling is an important method in experimenting with a radar system in proving a studied radar concept or in the early stage of radar system development. Several previous research reported the use of SDR in radar modeling [1, 2, 3]. However, existing SDR devices do not yet support the wide and ultra-wideband (UWB) operation. Vector Network Analyzer is a scattering parameter measurement tool for a Radio Frequency (RF) circuit or devices [4]. VNA consists of a signal source with a wide frequency range and a detector section. VNA has at least 2 ports that can each be functioned as a signal source or as a detector in S-Parameter measurement. Referring to the measurement capabilities of both ports, the VNA can be employed as transmitters and receivers, therefore the VNA can be utilized for modeling a radar system in an experiment as discussed in [5]. This paper will be discussed the concept of radar modeling using VNA. Some of the results of radar modeling experiments were shown and discussed. In the second section, the basic concept of radar modeling is explained using VNA which can be done for several experiments. In the third section, some radar system modeling setups were discussed and the results were obtained. Then the last is the conclusion.

II. Radar Modeling Using VNA

The basic principle of radar modeling using VNA is derived from the measurement setup in Fig.1.a. When both VNA ports are connected to the antennas then the results of the measurement results of S_{21} data will represent the transfer function between the received signal and the transmitted signal. The transmitted signal is determined based on the type of radar that want to be modeled. For example, when the modeling is done for Frequency Modulated Continuous Wave (FMCW) radar system than the $S_t(t)$ is a chirp signal with a certain period and bandwidth. Then the chirp signal that received by the radar system $S_r(t)$ can be determined respecting the relation on (1) and (2).

$$S_r(f) = S_{21} S_t(f) \tag{1}$$

$$S_r(t) = F^{-1}[S_r(f)] \tag{2}$$

Radar Modeling Setup using VNA is shown in Fig.1.b.

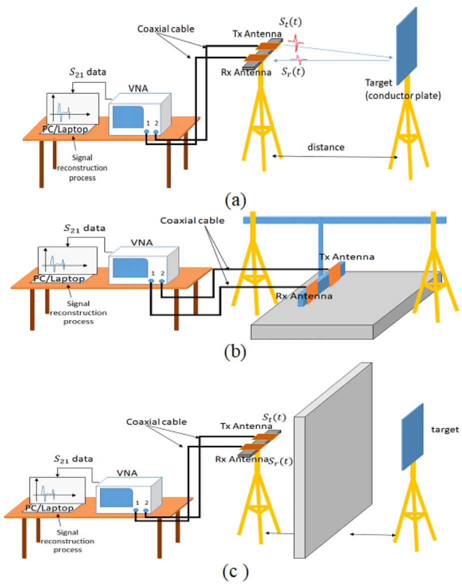

Fig. 1. Illustration of radar Modelling using VNA. (a) Basic Setup. (b). Ground Penetrating(GPR). (c).Through the Wall.

The model consists of 2 antennas connected to VNA ports. Furthermore, the VNA is set to perform S_{21} measurements on the frequency range of the radar system. The S_{21} data is then sent to the Computer for a received signal reconstruction process. The other processing that is required for a certain radar topology or detection cases can be developed on the computer side. The steps of radar modeling are detailed as follows :

1) Arrange the equipment that used for radar modeling as depicted in Fig.1b.
2) Setting up the VNA that includes frequency range, number of sample measurement data. The number of samples in the frequency domain is determined according to the sampling frequency that is used in generating

the transmit signal sequence. The measurement is set for S_{21} with a complex data format.

3) Read S_{21} data on the computer and compose the FFT sequence of S21 as a transfer function which is then written as $S_{21}[k]$.
4) Generate the sequence of the transmitted signal ($S_t[n]$) according to the radar system that simulated and then transforms it into the frequency domain using FFT that was written as $S_t[k]$.
5) Perform convolution between the transmitted signal and transfer function for obtaining the received signal. Multiplication in the frequency domain between $S_t[k]$ and $S_{21}[k]$ and followed by performing inverse FFT.

The other computation that is needed for further processing of received signal sequence, for example, mixing, filtering, or detection method can be flexibly developed in the computation domain.

III. Modeling Result

The experiments were performed using VNA T5280A (800KHz-8GHz). Fig.2 shows the experiment result of the UWB radar system that was modeled using VNA. The setup is shown in Fig.1.a. The S21 data is recorded within a range from 800KHz to 8GHz. The conductor plate with a size of 30cmx40cm is employed as a target located at two different distances. The result shows that the time distance of reflected pulse from the main pulse represents the target distance. The ringing level that contributed by the antenna is also possible to investigate form this result. It?s mean that this model is also relevant to be applied as a method to analyze the radars antenna performance. Fig.3 shows the experiment

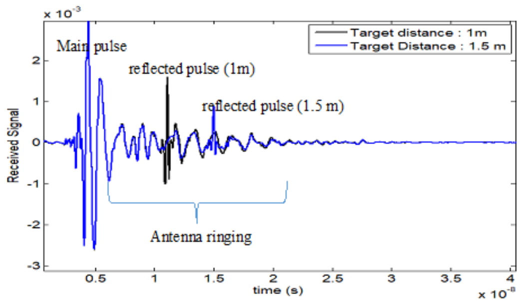

Fig. 2. UWB radar modeling experiment result.

result of FMCW radar system. In this experiment, the FMCW radar with a frequency of 2 GHz and the bandwidth of 200 MHz is modeled using VNA. The setup that was used is similar to the UWB radar experiment that was discussed previously. Fig.3 shows the spectrum of low pass filter output of FMCW radar. The frequency of the peak spectrum is used to estimate the target distance which also calls as beat frequency. The result describes that FMCW radar model demonstrates its performance in detecting the target distance. Fig.4.a represents the experiment result of concrete thickness

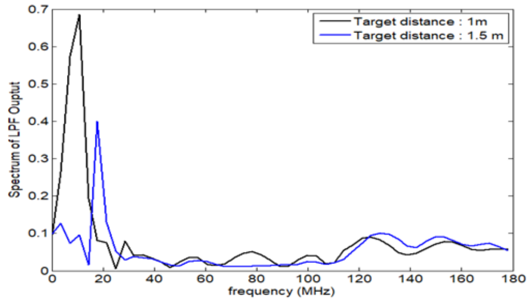

Fig. 3. FMCW radar modeling experiment result.

detection using a GPR system that is modeled using VNA as shown in Fig.1b. Fig.4b shows the experiment result of Through the Wall (TWR) Radar system that modeled using VNA as shown in Fig.1.c. The result in Fig.2-4 demonstrate that radar modeling using VNA can be applied for variate radar topologies and detection cases.

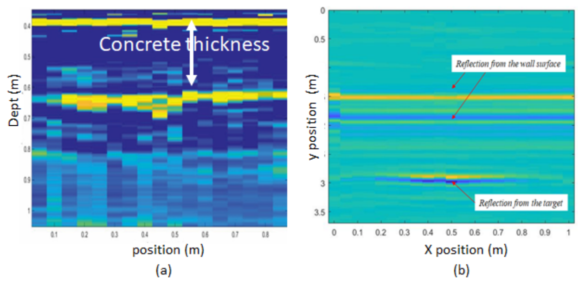

Fig. 4. Modeling experiment result.(a). Ground penetrating radar. (b). Through the Wall.

IV. Conclusion

The Radar modeling concept using VNA has been discussed in this paper. Several sample experiments that employed this concept have also been discussed. Radar modeling using VNA has very useful in performing radar experiments. The modeling result demonstrates a good representation of the observed radar system. This method provides flexibility in performing many radar topologies and detection cases.

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