An Automated Microwave Imaging Testbed.

J.C. Vardaxoglou, R.D. Seager and P. Houliaras.

Antennas and Microwaves Group
Department of Electronic and Electrical Engineering
Loughborough University
Loughborough LE11 3TU

Abstract

A prototype testbed designed for the evaluation of microwave imaging algorithms is described in this paper. The microwave signal is supplied by a Flann Microwave Instruments 449X signal source and is processed by an Hewlett Packard 8410B Vector Network Analyser working in CW mode. The magnitude and phase of the required signal are obtained from an HP8414B polar display unit as DC voltages. A turntable, powered by a geared stepper motor, has been constructed to rotate the target. This allows a light target to be rotated in front of a transceiver antenna connected to an HP8743A 2-12.4GHz Reflection/Transmission Test Unit. The turntable and the 8410B are controlled by a PC running LabView®.

Introduction

This project was conceived for two main reasons. The first of these was the development of a testbed for imaging algorithms being developed for a medical imaging project [1]. The second was the possible applications of a system like this in both postgraduate and undergraduate teaching. The work presented here is the result of the first stage of development in that the user interface is not optimised but the system has been shown to acquire data and control the hardware as required.

System

A block diagram of the overall system is shown in Figure 1. We use dated equipment which does not have much other use in a modern microwaves research laboratory. Currently we are running a CW measurement using a Flann Microwave source . Using this equipment signal stability is not ideal but has been adequate for system development. The Hewlett Packard HP8743A Reflection/Transmission Test Unit is used to separate the forward and reverse signal. The reflected signal and the reference are passed to the HP8410B Vector Network Analyser for processing.

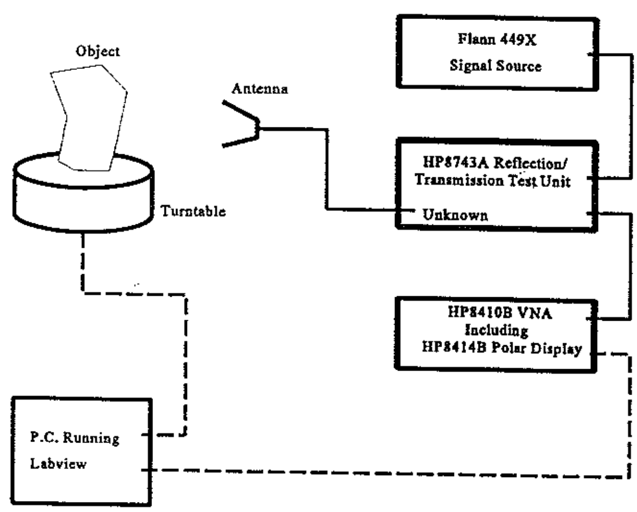

Figure 1. Block Diagram of Imaging System

We use the voltages corresponding to the X and Y positions of the measurement on the polar display to extract the magnitude and phase values for the 'reflection coefficient' of the unknown object. Care has to be taken in setting the gain levels in the from the network analyser in the correct LabView window. Also, by adding attenuators to the R.F. channels an improvement in system sensitivity can be obtained. This can be particularly important for diffuse or poor reflectors.

Currently we calibrate the measurement system manually using three standard terminations to achieve a set of 1-port error terms giving directivity and source match. Frequency tracking is not an issue here because we work at a fixed frequency.

LabView Virtual Instruments

The heart of the system is the National Instrument's LabView. LabView is a Microsoft Windows programme designed to allow control of data acquisition and hardware control through a user defined graphical interface. It drives, in this case, a Lab PC+ multifunction PCB. This board supplies analogue and digital inputs and outputs as well as timing and counter functions. The analogue input and output is via Analogue to Digital and Digital to Analogue converters. The board supplies 48 digital inputs which may be selected as either input or output.

LabView comes with a comprehensive library of functions (Virtual Instruments) to interface with the Lab PC+ board. Using these to develop control instruments for the turntable and the acquisition of data from the HP8410B provides a set of low level functions suitable for the development of the top level Virtual Instrument such as that shown in Figure 2.

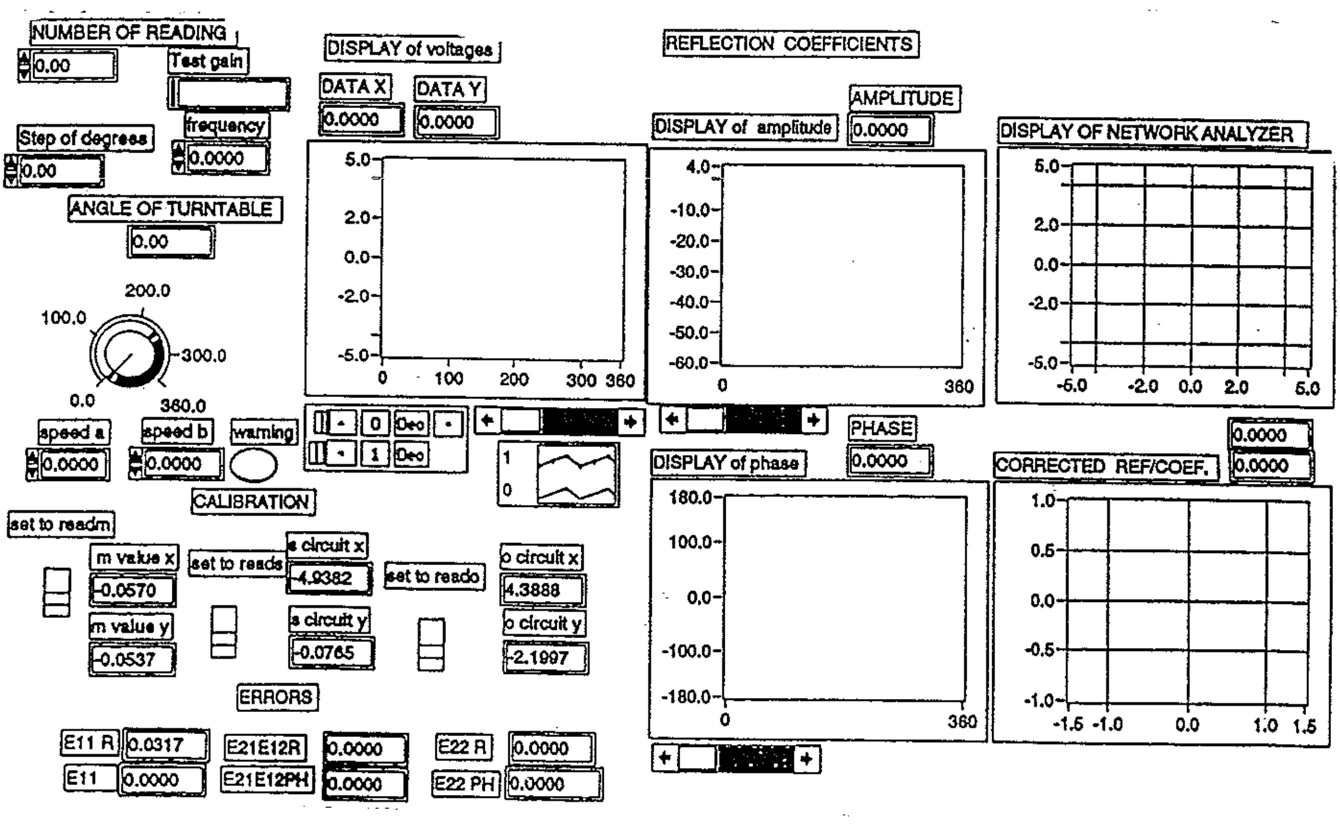

Figure 2. Virtual Instrument Front Panel

The virtual instrument shown in Figure 2 is developed from control blocks designed to acquire data from a port on the PC+ card and to provide a 4 BIT parallel interface as described for the turntable control. The screen can be divided into different regions. In the top left corner are the input panels for the frequency, the microwave test set gain and the number of readings required. Just below this are the turntable control functions. Below this are the readings taken from the calibration procedures for the three standard terminations and the calculated error terms obtained from the calibration.

The remainder of the screen is given over to displaying the data obtained from the Polar Display Unit. This includes the uncorrected and corrected data from the Display Unit as well as the corrected Reflection Coefficient. The complete system can be controlled using the switches and panels on this screen. There is considerable data being displayed on this screen that makes it appear somewhat crowded. This extra data (Display Unit data and error coefficients) is used for system validation during development and can eventually be removed allowing a more intuitive interface to be defined.

Turntable Control

As far as possible, the turntable is constructed from insulating material. It is driven by a geared stepper motor controlled from a computer by a four bit parallel interface. Three bits are used to control the motor and the fourth is to detect the nominal zero position using an optical sensor. The control bits enable the system, set the direction and step the motor, once for each pulse. A standard stepper motor control chip (SAA1027) is used. This parallel interface can either be the PC printer port or a purpose built interface card. Based on generic LabView virtual instruments we have defined an interface to control the step size, direction and rate.

Results

We present two measurements for a metallic cylinder offset from the turntable axis of rotation and a table of comparisons with our automated HP8410B Vector Network Analyser. Figure 3 shows the uncorrected reflection coefficient measurement. Figure 4 shows the corrected reflection coefficient measurement.

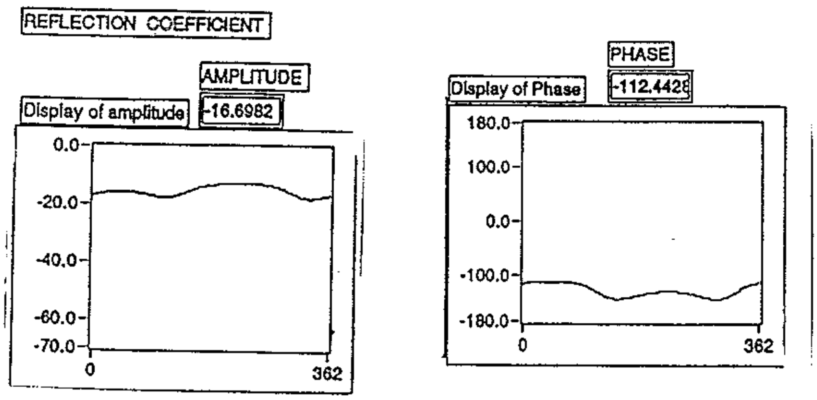

Figure 3. Uncorrected Measurement of Offset Metal Cylinder.

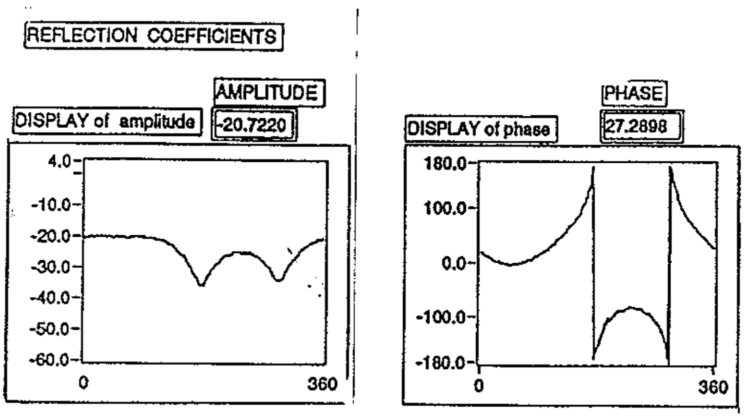

Figure 4. Corrected Measurement of Offset Metal Cylinder.

The differences between the two sets of measurements are obvious. Both the phase and amplitude plots on the corrected data show more clearly the varying reflections from the cylinder. Table 1 shows a set of comparisons of measurements made with the LabView system and our automated HP8410B VNA.

		LabView System		**HP8410B VNA**	
Device	Frequency (GHz)	Amplitude (dB)	Phase (Degrees)	Amplitude (dB)	Phase (Degrees)
Open Circuit	9.048	-0.11	-25.68	-0.02	-26.4
Short Circuit	9.048	0.06	179.86	-0.08	179.7
50Ω Load	9.048	-53.66	117	-63.04	-87.3
Horn Antenna	9.048	-20.3	5.44	-20.54	3.4
Open Circuit	9.211	0.01	-26.01	0.00	-26.1
Short Circuit	9.211	0.001	179.99	-0.05	179.6
50Ω Load	9.211	-60.43	-172	-62.03	-95
Horn Antenna	9.211	-21.95	21	-22.05	21.1

Here we see reasonable agreement for both open and short circuit terminations. The agreement between the two measurements of matched loads is, unfortunately, not good enough yet. The horn antenna measurements compare well. There is some variation in the phase angle at 9.048GHz which might require further investigation. We have recordeed a dynamic range of 44dB with a test gain of 30dB. By using attenuator pads within the RF channel we believe we can improve this figure.

Conclusions

The system described in this paper is in the early stages of development. From the results presented here we can say that we can acquire data from an HP8410B VNA to allow us to perform error correction calculations. Some of the comparisons presented show greater differences between the LabView system and the automatic VNA than we would wish. This requires investigation while the system is being developed further. This is particularly true for the measurement of a matched load. This might imply that the source match error term is not determined as accurately is necessary.

We have measured a rotational speed of about 36° per minute. This figure is dependent on a variety of factors including the loading on the turntable and the gearing used for the stepper motor.

With the addition of some hardware and a GPIB card the network analyser can be further automated. The final addition needs to be a GPIB controllable synthesized source, allowing multiple frequency measurements to be obtained. Currently we are considering the accuracy variation and also defining file formats for the data obtained so that it can be fed to image processing software.

The possible uses of a system such as this in an academic laboratory are many. We feel we have a prototype system that will eventually allow us to study image processing algorithms. We also can use the system as a teaching aid in our variety of microwave based courses. The system lends itself to upgrade as equipment and finance permit.

References

1. R.D. SEAGER, M. JAYAWARDENE, J.C. VARDAXOGLOU G.R. CHERRYMAN AND M HORSFIELD. 'Evaluation of a Frequency Selective Horn Antenna for use within a Magnetic Resonance Imaging System' Proc. 23rd Automated RF and Microwave Measurement Society Conference. 25-26 September 1995, Windermere.