

ZERO BALANCE PHASE MEASUREMENT

by Walter J Kaminski

A zero-balance phase measurement apparatus includes first and second hybrid couplers, each of the hybrid couplers including an input port for receiving an RF signal, and first and second output ports, the second output port generating a 90-degree phase shift relative to the first output port. The first output port of the first hybrid coupler and the second output port of the second hybrid coupler are connected to first and second inputs, respectively, of a first phase detector. The first output port of the second hybrid coupler and the second output port of the first hybrid coupler are connected to first and second inputs, respectively, of a second phase detector. The apparatus is configured to generate a zero-balance phase output signal as a function of first and second phase difference signals generated by the first and second phase detectors, respectively.¹

I. Introduction

The Hybrid Couplers 202 and 204 each generate 0- and 90-degree outputs from 206 and 208 input signals, as shown in Figure 1. The 0-degree and adjacent 90-degree outputs are connected to Phase Detectors Ch1 and Ch2 inputs, respectively. The Phase Detectors generate a P1 phase and P2 phase; representative of a zero-balance phase measurement of the input signals.

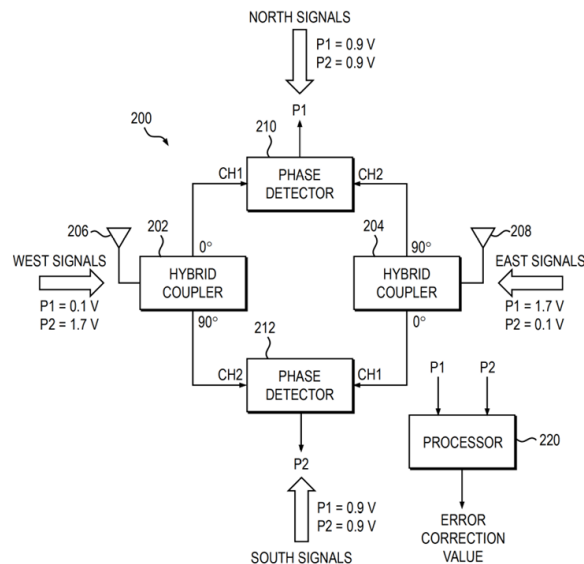


Figure 1: ZBPM circuit

Figure 2 shows phase detector P1 and P2 outputs in relation to Figure 1.

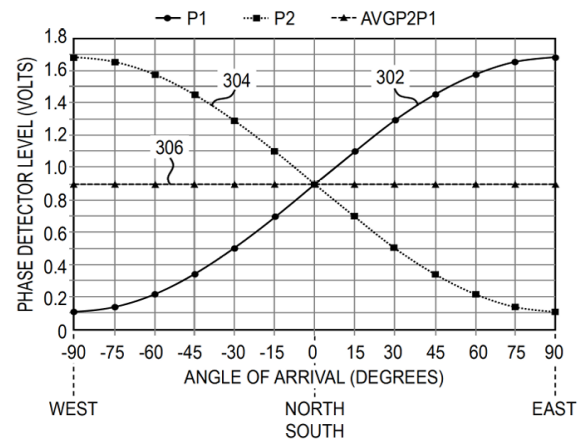


Figure 2: ZBPM P1 and P2 Voltage Out at AOA

The Printed Circuit Board PCB layout is shown in Figure 3 populated with the Hybrid Couplers.

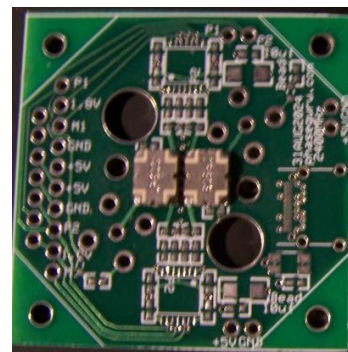


Figure 3: ZBPM PCB 41x41mm

II. Results

Figure 4 illustrates a configuration with antennas and 5mm bore flange for stepper motor mounting and turntable testing. Turntable test results using 2 antennas are shown to the right for 2350MHz, 2400MHz and 2450MHz.

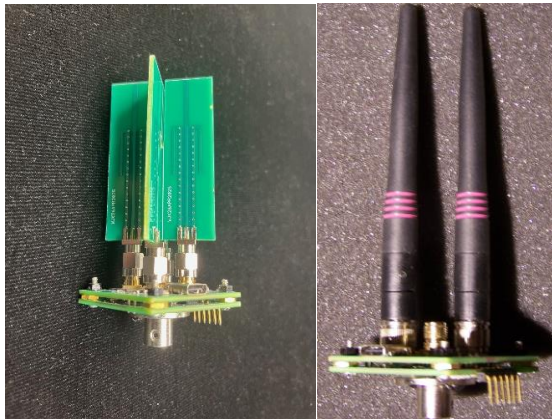
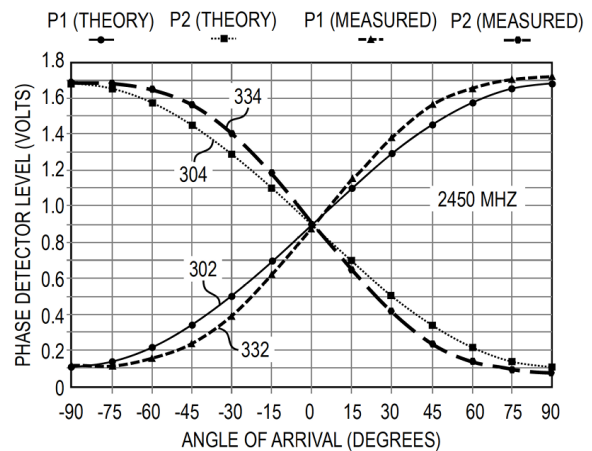
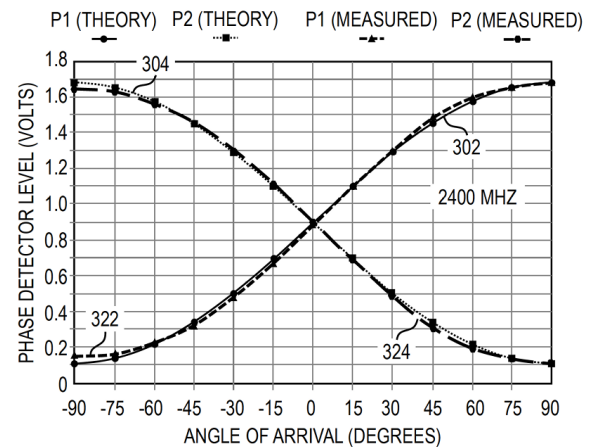
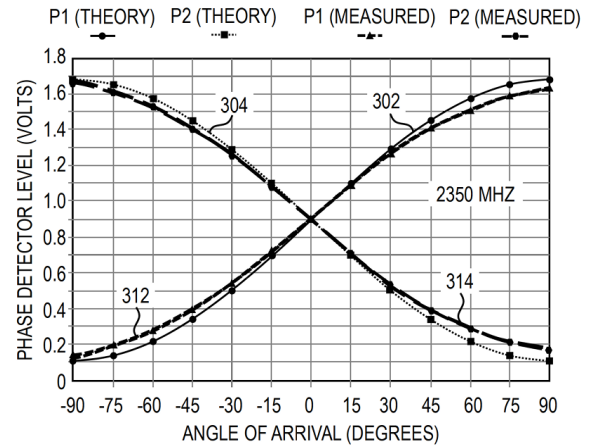
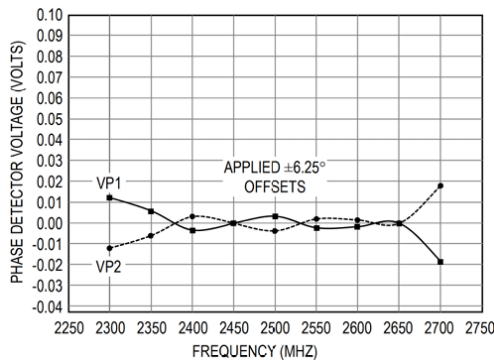
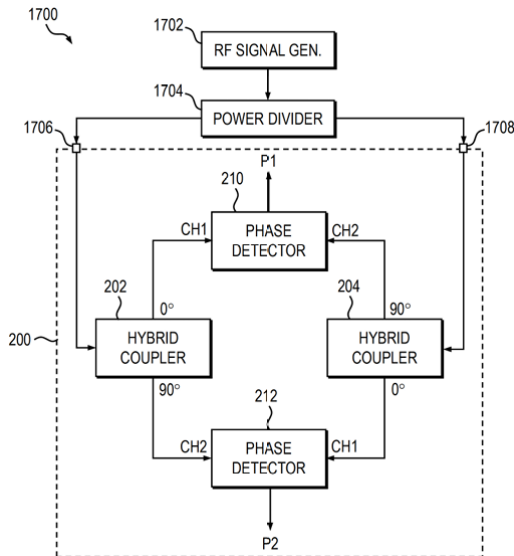


Figure 4: on the left ZBPM Circuit PCB Antenna (4ea) and on the right ZBPM Circuit using Off the shelf antennas (2ea)



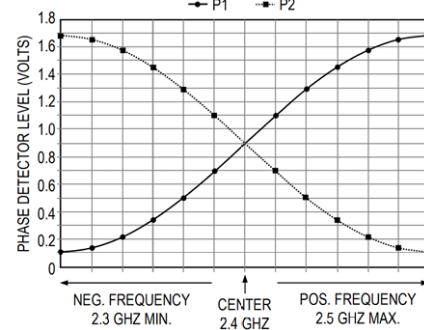
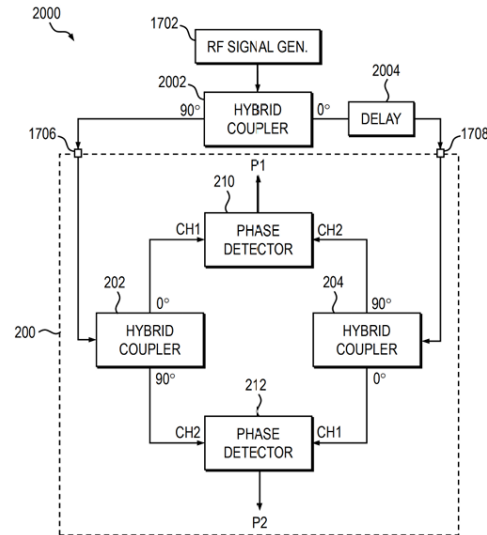
III. Conclusions

Reduced phase errors using a compact printed circuit board (PCB) integrated antenna/zero-balance phase measurement circuit design; may be configured to measure phase balance on paired dual channel circuits (e.g., dual channel RF amplifiers, filters, switches, etc.) where accurate dual channel circuits require zero phase balance across a frequency band of interest as illustrated in the following figures the phase balance is on the order of ± 1 degree ($0.01\text{Volts}=1$ degree)



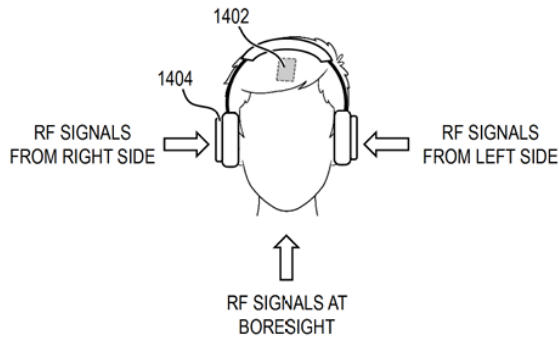
and may be configured to incorporate instantaneous frequency measurement (IFM) using a zero-balance phase measurement circuit with front end delay line and Phase Detector Level (Voltage) output versus frequency response curves as shown in the following

figures; and may be configured to use frequency information for making adjustments to phase slope constants, which will reduce AOA errors while operating in different portions of the frequency band (Replace the RF Signal Generator with an antenna for RF signal reception over the air);

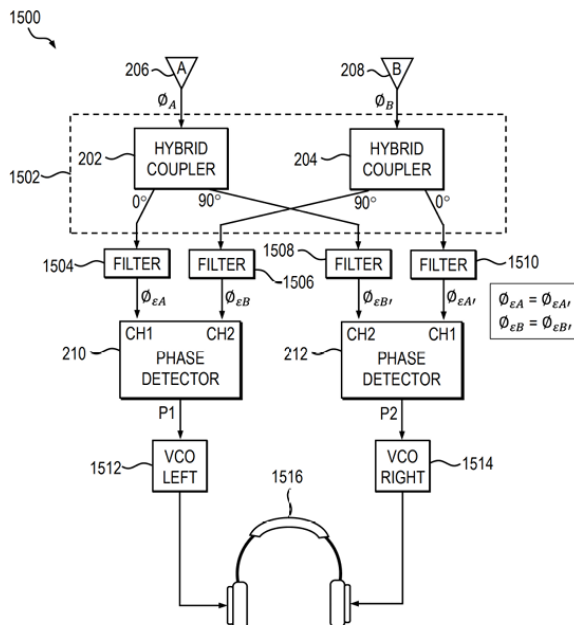


easy to fabricate using standard and repeatable PCB manufacturing processes; plug and play compatible design; scalable antenna sizing and spatial dimensions configurable for use with different frequency bands of RF signals depending on the application; configurable as a phase direction finder sensor that integrates into a reduced package size ideal for mounting on small platforms, including hand-held units and wearables.

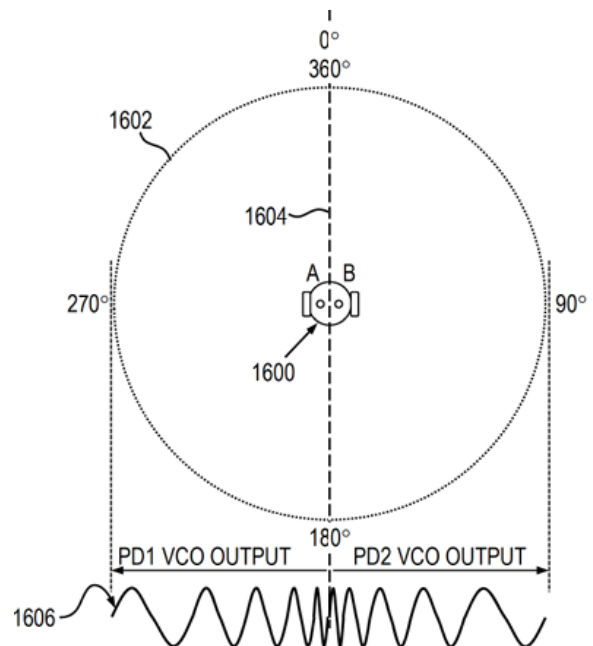
When used as a tracking device (e.g., wearables), the figure below illustrates a wearable device 1402 for example, attached near the head (in a hat, in a helmet, etc.)



The wearable device is configured as shown below in the following figure



A person wearing the device will hear an output tone in either the right or left ear (towards the direction of an RF signal beacon). Upon hearing a tone, the user would turn in the direction of the tone until the tone crosses to the other ear and when this occurs the RF signal beacon is in front of the user (RF SIGNALS AT BORESIGHT)



References

- [1] W. J. Kaminski, "Zero Balance Phase Measurement Circuit". United States of America Patent US12,287,415B1, 25 April 2025.