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RFID SENSOR NETWORK FOR OBJECT TRACKING SYSTEM

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Factories are an important factor for the growth and development of counties, as well as an engine and a driving force of their economy. Recent advancements of technology made factories evolve progressively through introducing more and more innovative tools and ideas. Computer and communication technologies have greatly influenced the structure and the organization of factories and the process of manufacturing. Companies have used technologies to automate assembly lines, to control and to monitor products while moving on them.

In recent years auto identification systems have been gaining lots of attention from various application domains such as security, industry, sports, transportation, education, and manufacturing. A radio frequency identification (RFID) wireless system is a powerful tool to detect the presence or absence of objects and to know their relative positions. Utilization of RFID systems has great benefits for improving the manufacturing process in factories.

In the work [1] an RFID based object tracking system to automate assembly lines was developed. Authors followed a grid based approach where RFID readers are spread over the factory as a grid at defined positions Figure 1. The main objective is to predict the location of an object to improve the efficiency of assembly line operations. They used a convex based range free tracking algorithm [2]. When several RFID readers read a certain tag attached to moving object, its position is within the intersection of the ranges of the readers. The system only indicates the predicted location of moving objects throughout the assembly lines.

The read/write range performance of a RFID system depends mainly on the choice of frequency, radiated power from the reader, sensitivity and modulation efficiency of a transponder, data rate, reader receiver sensitivity in the presence of self-jammer signal and location of the transponder [3]. The biggest challenge for the receiver front-end is to handle leakage from the full power continuous wave (CW) signal being transmitted during reception to keep the passive transponders powered up. This calls for the design of a wide dynamic range receiver or a use of some sort of an isolation approach, or self-jammer cancellation technique. However, the isolation between transmitting and receiving channels increases the RFID reader cost. Leakage canceller complicates the reader receiver and adds to the reader’s consumption that is critical for mobile applications [4].

This paper proposes RFID reader based on the special type automatic network analyzer (ANA), which working frequency range may be secured by the appropriate ports’ arrangement along the ANA longitudinal axis. The suggested approach does not require the carrier signal reader compensation. The basic tendency of development of automatic measurement systems in microwaves are the improvement of accuracy, objectivity as well as measuring rate. As a consequence it stimulated the appearance of new methods of measuring data processing using microprocessors or various computers. At present two main techniques are used for automatic measurements of microwave circuit parameters, namely, vector voltmeter and multi-port reflectometer.

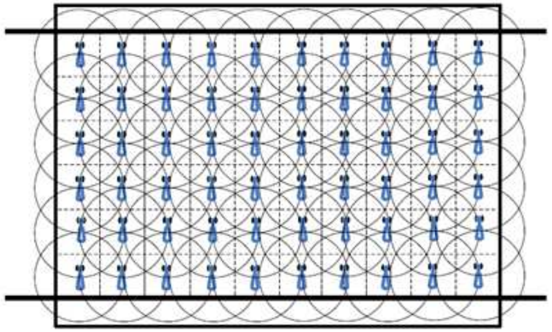

Figure 1: Tracking system in assembly line

ANA based on vector voltmeter (VV) are well known [5], [7]. Their great advantage is extremely high accuracy of measurements. But from the other hand, they are rather expensive because of the several reasons. Before coming to complex ratio meter the ANA's signals proportional to incident and reflected wave magnitudes are passed through the analogue signal processing unit containing the complex and expensive circuits of automatic gain control, phase lock loop, phase detectors, etc. Besides, the large kit of precise calibration standards is required at every measurement frequency to make up the imperfect responses of directional couplers extracting incident and reflected waves. The use of couplers with high direction (> 40 dB) can diminish considerably this source of errors but leads to rise in cost of the whole ANA. Therefore, it will be a good idea to eliminate the unit of analogue processing including the complex ratio meter entrusting its functions to computer that can take account of imperfect performance of directional couplers. Moreover, it becomes possible to refuse the couplers themselves using the simple voltage meters instead.

The ANA based on multi-port reflectometer (MR) has substantial merits [6]: high accuracy and simplicity of design due to absence of analogue processing circuits. But the use of power meters makes the set of equations for MR nonlinear obstructing the optimal signal processing of measurement data. Furthermore, the technique is very sensitive to own parameters of reflectometer to be determined during the calibration procedure [6]. So, very strict requirements are imposed on MR design in order to avoid a solution ambiguity of quadric multi-port equations caused by noise errors of power meters. That is why the stability of solution is traded off for use of directional couplers, phase shifters, delays, etc. But such a sophistication of design disagrees with the main advantage of ANA based on MR: its simplicity and cheapness.

The comparative analysis of these techniques allows the authors to put forward the idea of creation of ANA combining their advantages and avoiding their demerits. The idea of removal of analogue processing units and directional couplers with concurrent keeping the set of ANA equations to be linear with respect to unknown variables is very attractive since it becomes possible to apply the optimal techniques of data processing and estimation of parameters to be measured. The authors made an attempt to combine the advantages of both conventional techniques and eliminate their main drawbacks. For that purpose they designed the ANA which block-diagram is shown in Figure 2.

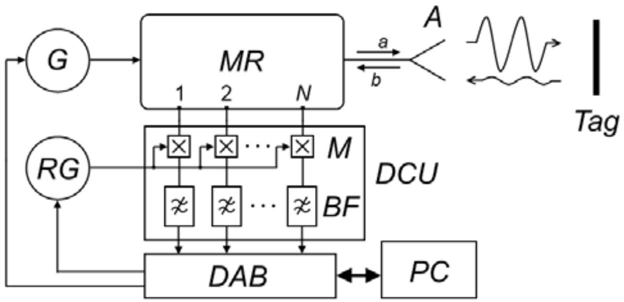

Figure 2. The block-diagram of proposed ANA based RFID reader: *G*, *RG* are microwave generator and reference generator; *MR* is multi-port reflectometer; 1, 2, ..., *N* are measuring ports; *A* are antenna; *M* are mixers; *BF* are band-pass filters; *DCU* is down conversion unit; *DAB* is data acquisition board; *PC* is personal computer

The technique consists in use of MR in combination with down conversion of measurement frequency inherent to ANAs based on vector voltmeter. The outputs of measuring ports of MR are connected to the mixers of frequency conversion unit instead of power meters. After the heterodyning the analogue audio frequency signals proportional to probes responses are sampled by the data acquisition board and entered to computer memory. All the subsequent processing of obtained data performed in the digital form using the special software.

Here the output digital signals of the DAB are linear functions of the estimated parameters *a* and *b*. Hence, they may be processed without the loss in signal-to-noise ratio and parameters of the load under test can be measured with potentially achievable accuracy.

The algorithm for measurement of module and phase of tag signal is designed and developed in the work [8]. Results of computer simulation of measuring process confirming the theoretical conclusions are shown in the Figure 3. It presents the dependencies of mean squared estimation error for the complex reflection under test modulus and phase versus power signal-to-noise ratio (SNR).

The design of this ANA is rather simple. It may be a segment of a microwave tract with the ports located along the longitudinal axis. The wide frequency range of

the proposed multi-port based ANA is achieved by the appropriate ports' arrangement inside the junction. The theoretical basis of this arrangement selection is givenen in the work [9]. The named work has shown that it is possible to cover extremely large frequency range using only 8-10 measuring ports.

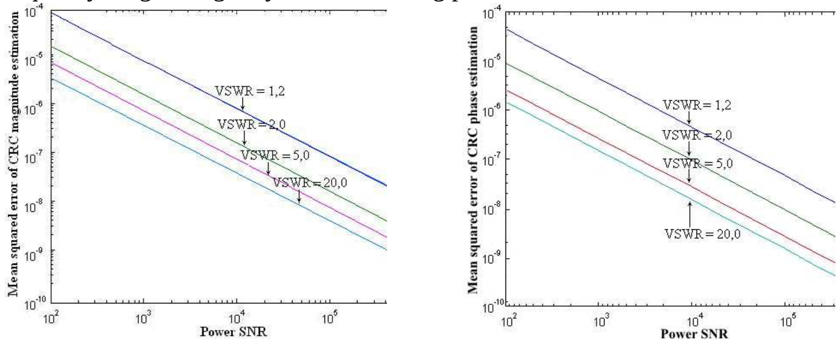

Figure 3. The dependencies of mean squared errors of magnitude and phase estimators of the complex reflection under test on the power SNR for different voltage standing wave ratios (VSWR)

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CALIBRATION ALGORITHMS FOR SOFTWARE DEFINED RADIO APPLICATIONS

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1. Introduction

Today the evolution toward practical software radios is accelerating through a combination of techniques. These include smart antennas, multi-band antennas, and wideband RF devices. Nowadays wideband analog-to-digital converters (ADCs) and digital-to-analog converters (DACs) can access GHz of spectrum instantaneously, Intermediate Frequency (IF), base-band, and bit stream processing is implemented in increasingly general purpose programmable processors with Application-Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), Digital Signal Processors (DSPs), and general purpose (GP) processor technologies are being introduced in SDR designs. SDR is becoming practical as costs per millions of instructions per second (MIPS) of DSPs, and general-purpose central processor units (CPUs) have dropped below $10 per MIPS. The economics of software radios become increasingly compelling as demands for flexibility increase while numerical processing costs continue to drop by a factor of two every few years but RF parts and sub-assembly costs tend to remain high particularly at millimeter wave frequencies. At the same time, absolute processing capacities continue to climb into the hundreds of millions of floating-point operations per second (MFLOPS) to billions of FLOPS (GFLOPS) per chip. At present time, software radio technology can be cost-effectively implemented for commercial first-generation (1G) analog and second-generation (2G) digital mobile cellular radio air interfaces. Over time, wideband third generation (3G) air interfaces will also yield to software techniques on wideband RF platforms possibly at millimeter wave frequencies. The resulting software-defined radio extends the evolution of programmable hardware, increasing flexibility via increased programmability. The ideal software radio represents the point of maximum flexible programmability in this evolution. In addition, ADCs and DACs are available as low-cost chips and single-board open-architecture configurations offer bandwidths of tens of MHz with the dynamic range required for software radio applications. Multimedia requirements for desktop and wireless personal digital assistants (PDAs) continue to exert downward pressure on parts count and on power consumption of such

chip sets. This trend will push the ideal software radio technology from the base station to the mobile terminal. Although the tradeoffs among analog devices, low-power ASICs, DSP cores, and embedded microprocessors in handsets remain fluid, cutting-edge base stations are beginning to employ software radio architectures. New designs for high-end mobile radio nodes such as military vehicular radios are now largely based on some type of software radio approach.

Finally, the multi-band, multi-mode, and multi-user flexibility of software radios appears central to the goal of seamless integration of personal communications systems (PCS), land mobile and satellite mobile services (including truly nomadic computing). Compared to the traditional hardware radio, the main advantage of software radio is the fact that it can support various modulation schemes with a unique hardware. On the other hand, its main disadvantage is still the present high cost of digital programmable devices. This situation can change with the rapid development in semi-conductor processing technology and the development of re-configurable devices in combination with six-port receiver technology [2].

2. Calibration

It is possible to calculate the ratio of amplitude, frequency and phase between LO signal (port 1) and RF signal (port 2) from the four output power levels determining the complex constants X_i, Y_i by calibration procedures. We now examine the six-port calibration method and the six-port receiver demodulation results obtained with calibration. Among the many algorithms that have been proposed for the physical calibration of six-port reflectometers (SPR's) [7], Engen's six-port-to-four-port reduction [5], [1] seems to be the most attractive. This procedure determines the dependencies between the different power meter readings, yielding five real-valued reduction parameters that permit to transform the SPR into a virtual four-port. No known standards are required for this reduction. The value measured by the virtual four-port is related to the reflection coefficient of the device under test by a so-called "error box" transformation. The three complex parameters of this transformation may be found by using one of the many existing methods for the calibration of traditional network analyzers. Recently, some real-time six-port calibration algorithms were proposed. These calibration algorithms are designed for six-port direct receivers, a brief description of these calibration methods are given here.

3. Physical six-port calibration method

W-plane calibration of six-port circuit

Using the same annotation as Stumper [3], the six-port to four-port reduction is given by the equations

$$p_1 = |w|^2 \quad (1)$$

$$Zp_2 = |w - w_1|^2 \quad (2)$$

$$Rp_3 = |w - w_2|^2 \quad (3)$$

where w is the complex reflection coefficient at the input of the imaginary ideal four-port reflectometer and the p_i denote the power levels p_1 to p_3, measured with the SPR significantly.