Multifunction calibration

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Abstract— In this paper, a receiver architecture is presented which is capable of handling angle-of-arrival (AOA) detection as well as data communication. The architecture of the proposed multifunction receiver is based on the multiport interferometer technique, and it integrates two previously reported six-portbased system functions that were realized as two distinct six-port receivers (SPRs). This unification of two SPRs is mainly achieved through a new configuration of RF/local oscillator (LO) signals at input ports, a new phase processing of the input signals within a structured eight-port passive network and a complementary postprocessing of the signals at the output of detectors. Using two RF input ports and two LO input ports that are switched in two consecutive time slots, the proposed multiport-based receiver (MPR) can estimate the AOA with a simple signalprocessing algorithm. The plurality of the RF input ports can cause self-interference for the received communication signals. Therefore, a phasing network within the proposed eight-port wave correlator is devised such that the incoming quadrature modulated RF carriers are demodulated in an orthogonal manner at four output ports. It is found that receiving communication signal from a nonzero AOA makes imbalance between demodulated components. To this end, the proposed MPR can first find the angular position of the other unit and then recover the demodulation components through data fusion and postprocessing. The mathematical model for the developed MPR is derived along with the development of an appropriate calibration technique, and its principal functionality is theoretically analyzed. In addition, a transceiver architecture based on this MPR is implemented, and prototyped for operation around 77 GHz. The techniques for hybrid millimeter-wave system integration are explained in this paper. The proposed concept is proven and concluded with satisfactory measurements for both functions. This unified multifunction MPR can find applications in the future vehicle-to-vehicle radios and joint radar-communication systems

Theoretical—This paper depicts an on location estimation program of the National Research Council of Canada (NRC). The NRC benefit gives alignments of the multifunction electrical models that electrical utilities and different associations use to test and check power income meters. The adjustment program can be utilized to demonstrate that the estimations of the power income meters are traceable to the national standard, a prerequisite of the exchange metrology enactment in Canada. Some alignment consequences of two kinds of regularly utilized electrical models are likewise talked about.

Index Terms— On-site calibrations, traceability, revenue meters, multifunction electrical standards

I. INTRODUCTION

I n India, all gadgets used to decide a charge based on a deliberate amount are managed under exchange metrology enactment. One of the necessities of the law is that the estimating gadgets must be aligned with guidelines traceable to the national standard of Canada, kept up at NRC. In the power exchange part this prerequisite has been translated to imply that all conceivable charging amounts of income meters must be traceable to the national standard. As a result every single electrical utility and different associations giving power meter alignment administrations keep up multi-work reference norms, which are intermittently adjusted to show traceability to the national standard. For a long time, customers requiring traceable estimations for their power meters needed to either send principles straightforwardly to NRC or to the alignment lab of the Canadian administrative organization whose measures are thusly traceable to the national standard at NRC. The presentation by NRC of an on location adjustment benefit, the NRC Traveling Standard Program, has given customers another viable technique for fulfilling the traceability prerequisites of the enactment as connected to multifunction power measures. Customers can inquire

NRC to change their measures nearby.The on location strategy comprises of providing the principles under test and a NRC PC controlled reference estimation framework with a similar voltage and current waveform. For each test, the beat yield of every standard is arrived at the midpoint of for 10 seconds and contrasted with the identical heartbeat

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rate ascertained by the PC to get the mistake of every standard under test. The test information is broke down and an adjustment report is issued by NRC demonstrating the contrasts between the gauges tried and the national standard for Canada. Throughout the years, NRC has created test hardware to help this Program [1], [2], [3], [4].

II. THE RERENCE SYSTEM

In the previous decade, there have been numerous adjustments in the charging practices of Canadian electrical utilities. Most new power metering gadgets are currently microchip based examining meters. The new meters can suit for all intents and purposes any income charging application. They can without much of a stretch measure at least fifteen distinctive charging amounts. The electrical norms used to check these new meters are additionally required to be multifunction and need traceability for various diverse amounts. To accommodate the expanded prerequisites for traceable electrical estimation amounts in a cost effective way, the Program now depends on a PC controlled estimation framework, which is utilized both as a source of perspective gadget and for the information accumulation and examination of the test outcomes got amid the on location alignments [4].

The reference estimation framework depends on two accuracy testing voltmeters, utilized as 18 bit A/D converters. The voltmeters just work on their 10-volt ranges since the info scaling is finished by custom-fabricated voltage and current information circuits. The voltmeters digitize the information voltage and current signs at 512 examples for every cycle. The computerized tests are exchanged through the IEEE-transport to the PC for figurings of the reference amounts and the identical heartbeat rate. The voltage contribution of the estimation framework is a 1 Mω stage remunerated resistive voltage divider. The yield of the divider is self-running and delivers a voltage of 7.07 Vrms for each inner voltage run 120, 240, 360, 480, and 600 V. The voltage dividers and its yield intensifier are aligned by applying known air conditioning voltages at the information sources and estimating the yield voltage of the speaker. Voltage divider remedies for each interior range are put away in the PC and utilized as a part of later estimations. The most extreme information voltage is 720 Vrms. The present contribution of the framework comprises of an electronically helped multistage current transformer [5] took after without anyone else extending current to voltage converter circuits. The yield of the current to voltage circuits is 7.07 Vrms, for the present range 0.25, 0.5, 1, 2, 5, 10, 25, 50 and 100 A. The circuits are aligned by applying known air conditioning streams at data sources and estimating the yield voltage. A remedy for every present range is put away in the PC and utilized as a part of the figuring schedules of every present estimation. The most extreme information current is 120 Arms.

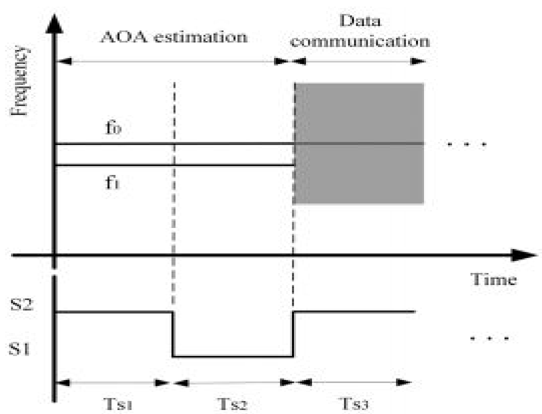
The product is composed in Visual Basic and was created particularly for this application. It is tweaked for every customer of the Program. The product is menu-driven and enables the administrator to streamline the adjustment method in view of the sort of standard and the estimation work being tried. It controls the test voltage, current, control factor, and test time, the information procurement procedure of the examining meters, and plays out the examination of the inspected information. All the electrical amounts utilized for charging customers in Canada are computed. The product can without much of a stretch be altered and new estimation capacities included as required.

Before each on location alignment, the blunders of the NRC reference framework and the mistakes

Table 7.2 Observation Table (VFD)

Flow	Head	Active Power	Reactive Power	Apparent Power	Power Factor	RPM
m^3/hr	m	KW				
3.81	5.7791	0.1413	0.033	0.1451	0.97380	2919
3.50	5.1055	0.1183	0.02733	0.1214	0.97434	2703
3.20	4.8520	0.099	0.02266	0.1015	0.97477	2465
2.90	4.1120	0.082	0.01633	0.0836	0.98073	2235
2.50	3.8996	0.065	0.012	0.0661	0.98338	1933
2.12	3.5542	0.0526	0.01	0.0536	0.98244	1632
1.51	3.0254	0.039	0.006	0.0394	0.98837	1172

of two business multifunction norms provided by NRC, are resolved for all the estimating capacities and test focuses asked for by the customer. The alignments are finished with the NRC Automated Power Calibrator [6]. These blunders are put away as remedies and utilized with the on location information to decide the mistakes of the customers' gauges. Test information is regularly acquired for streams of up to 50 An and voltages of up to 600 V



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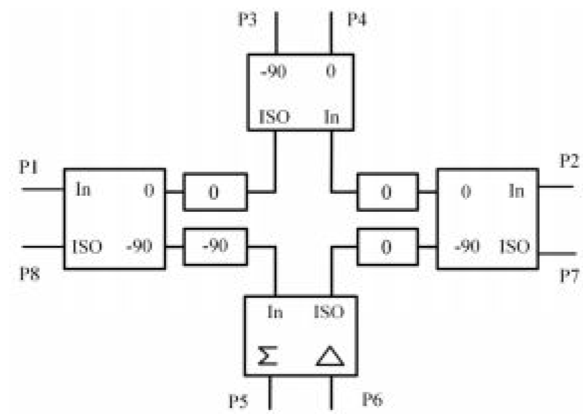
Common test outcomes have demonstrated that the exactness of the voltage and current estimations of the NRC reference framework is superior to 15 µV/V and 15 µA/A separately. The precision of alternate estimations is generally superior to anything 30 sections in 106.The two business norms are of various plan and have diverse mistake particulars, 0.02% for all capacities for the more up to date standard and 0.05% for watthour and 0.1% for alternate capacities for the second standard. Run of the mill consequences of the more current standard show that its mistakes are superior to 100 sections in 106. The second standard was acquired around 10 years back and its blunders are regularly in the scope of 300 sections in 106. The repeatability of the mistakes of the reference frame work, and the two business models when on location alignments are superior to anything 15 sections in 106, and superior to anything 30 sections in 106 separately.

III. ON-SITE CALIBRATION PROCEDURE

The NRC gear for on location tests comprises of a PC controlled reference instrument already depicted, a steady wellspring of AC voltage, present, dynamic and receptive power, and a 12-position beat recurrence comparator. Two business multifunction measures are likewise provided for the on location tests. To take out issues identified with the recurrence varieties of the line supply in the field areas, all the hardware utilized nearby including the principles under test are invigorated with air conditioning voltages and streams bolted to the recurrence of a different air conditioning power source which is additionally given by NRC.Before each on location alignment, a point by point guideline technique is arranged and put away in the PC that controls the on location tests. It incorporates estimating capacities and test directs mixes toward be confirmed, the test arrangement to be taken after, the associations of the voltage and current circuits of the reference framework and every single other standard to the AC source, the scope of the beat recurrence comparator, for each test point. A table of results is readied where test comes about are enlisted as a reinforcement to the PC records.

The on location adjustment technique comprises of providing the guidelines under test, the two gauges provided by NRC and the PC controlled reference estimation framework with a similar voltage and current waveform. For the test focuses, the recurrence of the beat yield of every standard under test is normally found the middle value of over a 10 second time span and estimated by the PC through a 12 position beat recurrence comparator. The deliberate estimations of recurrence are then contrasted with the equal yield recurrence ascertained by the PC from the deliberate amount of the examining framework. The outcomes are consequently recorded in a PC document and a mistake for every standard under test at that test point, which incorporates the redress for the NRC reference framework, is computed and put away. The beat comparator readings are likewise physically recorded as a reinforcement. The procedure is rehashed for each test condition required for the estimating capacity being checked. Up to 12 gauges can be aligned in the meantime. The legitimacy of the field information is quickly checked with a product routine whereby for each test conditions, after the mistake of every standard has been resolved, it is contrasted with beforehand gotten outcomes for a similar test conditions from up to 5 years of alignments. The blunders of the business gauges provided by NRC estimated nearby, are contrasted and the known mistakes of the two norms estimated at NRC. In the event that the blunders of these NRC business gauges estimated nearby concur firmly, 100 sections for each million (ppm) or better, with the outcomes acquired at NRC, it is sensible to reason that the field information for the NRC business measures is substantial and that the information got for the utility's norms tried in the meantime is additionally legitimate.

In the wake of finishing a total arrangement of tests for each estimating capacity of intrigue, the method is rehashed the same number of times as the on location test game plans will permit (for the most part 2 to 3 sets). For the estimating elements of Watthour, Varhour and Qhour, the mistakes of the measures under tests are characterized as the shown amount of the guidelines less the real amount which is equivalent to the demonstrated amount of the NRC reference framework utilized nearby in addition to any rectifications partitioned by the connected evident power. The blunders are communicated in parts per million. For the estimating elements of VAhour, V2hour, A2hour, Volts and Amps, the mistakes of the measures under tests are characterized as the demonstrated amount of the gauges short the genuine amount which is equivalent to the showed amount of the NRC reference framework utilized nearby in addition to any redresses separated by the real amount. These blunders are communicated in parts per million. A disentangled graph of the on location alignment associations is appeared in Figure 1



VI. PROTOTYPED TRANSCEIVER

Several remarkable features of the multiport interferometric technology, such as simplicity, low required power, and wide achievable bandwidth (BW), make it appropriate for applications around millimeter-wave frequency bands including automotive industry and backhaul radio connectivity. Therefore, the proposed multifunctional transceiver architecture is characterized, designed, and prototyped for operation around 77 GHz, which is demonstrated in Fig. 6. Some of the RF components including mixer, amplifier, switch, and the Schottky diodes are the commercially available off-the-shelf monolithic microwave integrated circuits dies which are integrated with the designed passive components such as antenna, filter, coupler, and eight-port network using our in-house monolithic hybrid microwave integrated circuits (MHMICs) and PCB processes. The details of the designed transceiver are briefly discussed next. A. Tx Block The block diagram of the designed Tx unit, along with the part number of the commercial components are depicted in Fig. 7. The LO signal at 70 GHz with the required power (15 dBm) at the mixer is generated using a cascade of frequency multiplier (HMC1105—Analog Devices TM) and an amplifier (HMC1144—Analog Devices TM). The transmitting IF signal is up-converted by a mixer (MDB277—Analog Devices TM) and amplified throughout a power amplifier (AUH320—Analog Devices TM). Two bandpass filters (BPFs) filter out the LO signal which is leaking out to the RF port of the mixer. A fourth-order substrate-integrated-waveguide (SIW) cavity BPF [46] is designed on 254-μm-thick alumina substrate (εr = 9.9 at 77 GHz). Fig. 8 shows a microscopic photograph of the prototyped filter which is fabricated using our inhouse high precision via-filled MHMIC technology. The vias in this filter were filled by gold for metallization purposes. The S-parameter measurement of the filter is carried out on a probing station. The microstrip-to-coplanar adaptor at the input of the filter was designed for modes transition between CPW ground-signal-ground (GSG) probe and microstrip input line

V. ON-SITE CALIBRATION RESULTS

In the course of recent years, around 50 power measures claimed by 8 distinct gatherings have been tried in any event once under the Program. Amid on location adjustments, four to eight principles are ordinarily confirmed over a time of one to three days. The quantity of test mixes can fluctuate from around 50 to more than 400 relying upon the metering practices of the specific utility gathering. Three arrangements of measures for an aggregate of 20 instruments are currently part of utility quality affirmation programs and are confirmed yearly. The others are endless supply of the customers. All the on location alignment comes about are gone into a database kept up at NRC. The outcomes examined are regular cases from the NRC database.

The outcomes appeared in Table 1 depict the long haul mistake execution of a standard aligned over an eight-year time span. The estimating capacities demonstrated are Watthour, Varhour and VAhour for the test mix of 120V, 5A and a power factor of 0.5 slack. The outcomes unmistakably demonstrate that the blunder execution of this standard for these three capacities is better that the

Around two years prior, another sort of multifunction power standard in light of an information examining configuration, was made accessible in Canada. The producer of this new standard has indicated its blunder as 0.02% for the majority of its estimating capacities. Some of these new measures have been aligned under the NRC Program. The test outcomes got hitherto plainly demonstrate that the mistake execution of this new standard for all its estimating capacities is superior to the 100 ppm or about portion of the blunder determined by the maker. There is no contrast between the execution of its watthour capacity and the various estimations as was apparent in the past age of principles. The long haul

mistake determined by the maker. It is likewise certain that the blunders of this standard for the watthour work are littler than for alternate elements of Varhour and VAhour. The long haul steadiness of the standard, appeared by the standard deviation of the information is also better for the watthour function. These observations are typical for this generation of electricity standard. These comments also apply to the other measuring functions of this type of electricity standard such as Volts, Amps, and Qhour, which are not shown in the Table. Most of the standards tested under this Program are of the same type as the standard whose results are shown in the Table. The performance of these other standards is similar to the example discussed here.

TABLE 1 LONG-TERM PERFORMANCE OF A MULTIFUNCTION ELECTRICITY STANDARD (ERRORS IN PPM).

Test point 120V,5A,PF 0.5 lag	Measured errors for: Watt	Var	VA
1998	57	-379	-124
1999	65	-267	-144
2000	69	-394	-141
2001	47	-361	-194
2002	114	-283	-85
2003	23	-350	-84
2004	71	-220	-252
2005	35	-221	-156
Average	60	-309	-147
Standard Deviation	28	70	56
Specifications	500	1000	1000

steadiness of the standard will be considered as more information winds up accessible.

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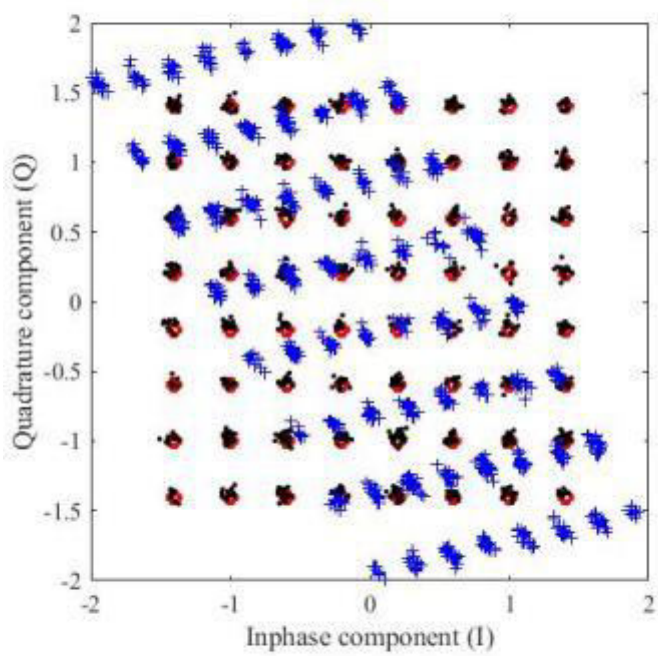
VII. CONCLUSION

A multifunction system scheme is proposed, analyzed, and implemented in this paper. It is mainly based on the technique of multiport interferometry and integrates two functions of angle detection and data communication through a simple architecture. Furthermore, two formerly distinct SPRs with different configuration of input signals are unified within a single multiport interferometric system through the proposed eight-port wave correlator and configuration of four input ports for RF and LO signals and four output ports for detected signals. The proposed multiport network features a new phasing condition to deal with the incompatibilities between the distinct system functions. Two different variants of the topology of passive network are also shown that satisfy the required phase condition. The proposed receiver is also mathematically modeled and its operation principles are analyzed theoretically. The AOA parameters of the incoming signal can be estimated through a simple proposed signal processing algorithm. A technique out of data fusion was also proposed for recovering the demodulated signal from the distorted I–Q output signals. To assess the presented concept, the multifunction eightport interferometric receiver architecture is employed in a complete transceiver and implemented for applications around millimeter-wave frequency bands along with an appropriate operational waveform scheme. In addition to the discussions for implementation of such integrated transceiver, system-level measurement results are presented for concept validation. One limitation of such multifunctional multiport-based transceiver is the short operational range, which is mainly because of the poor dynamic range of such technique. Another limitation exists in the proposed calibration technique and if the initial phase difference between two units changes after initial calibration, the calibration should be repeated. For AOA detection, single-frequency signals with a predetermined frequency difference are used. This may necessitate frequency synchronization before AOA measurements. In addition, relatively small measured BW of the designed diode detector limits the application of such multiport receiver to small data rate in comparison to large available BW around millimeterwave frequency bands. Conversion loss of the prototyped detector can be improved through biasing the diode [54]. To extend the dynamic range of an MPR, diode power detector can be improved to operate beyond the square-law region through diode linearization techniques [55]. Nevertheless, such Rx topology can find applications in the future 5G and future wireless systems including autonomous driving and self-adaptive mobile intelligence with the capability of communication. This would make the future multifunctional transceivers rather compact and low-cost alternatives of the tedious assembly of them on one platform. ACKNOWLEDGMENT The authors would like to thank J. Gauthier, who is managing the team of technicians at the Poly-Grames Research Center, for his considerable assets during fabrication process. The authors would also like to thank Analog Devices and Aeroflex companies for providing them with free samples of ICs and diodes. REFERENCES [1] L. Han and K. Wu, “Multifunctional transceiver for future intelligent



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