A SAW INTERFEROMETER DIRECTION - FINDING AND FREQUENCY IDENTIFICATION METHOD

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ABSTRACT

A technique is described, whereby both frequency and angle of arrival (AOA) information can be measured with high accuracy, on multiple simultaneously received signals. Such a technique is required in signal processing applications used to identify and locate agile parameter emitters in high density signal environments. This signal processing technique will be compared to other standard microwave signal detection, frequency, and AOA measurement methods.

INTRODUCTION

Various methods for measuring the frequency and direction of arrival of received signals exist to date. These methods include the Bragg Cell Acousto-optic processing, compressive receiver, and standard narrowband heterodyne techniques. A more recent technique, called the SAW Interferometer DF processor, will be described in this paper and compared against the above mentioned methods with regard to instantaneous bandwidth, phase accuracy, dynamic range and processing time.

The SAW Interferometer processor implements two chirp-Z Fourier transform processor channels driven from a common sweeping L O (Local Oscillator). The outputs of the two transform channels are fed to a phase comparator circuit that resolves the relative phase shift between the channel input signals. The frequency of the input signal can be derived from the time ordering of the appropriate energy spikes (transform coefficients) present at the output of the chirp-Z channels prior to phase detection. Signal AOA is measured by digital sampling the phase comparator outputs, followed by a simple calculation performed via a microprocessor. A standard compressive receiver by comparison, performs only energy detection. While compressive receivers can perform near real-time frequency measurement on multiple simultaneous signals, they are not capable of measuring signal phase. Acousto-optic techniques are capable of measuring both signal frequency and TOA (time of arrival), however, their processing time is relatively slow and requires complex support hardware. Standard narrowband heterodyne DF techniques are limited by their processing bandwidth and single signal processing capability.

COMPRESSIVE INTERFEROMETER IMPLEMENTATION

The basic implementation of a compressive interferometer receiver, neglecting the front end amplifiers and signal down/up converters required to heterodyne the band of interest into the IF processing band, is shown in Fig. 1. As indicated in Fig. 1 channels 1 and 2 are fed with identical, but phase-shifted, signals similar to those obtained by connecting the channels to individual, spatially separated antennas. The chirp waveform used to multiply the input signals is generated by impulsing an up-chirping SAW pulse compression line (PCL). The chirp filter, PCL 1, expands the impulse source into a linear (FM) frequency -modulation sweeping signal, which multiples the input signals on both processor channels. The PCL 2 matched filters perform the actual transform processing and output the signal spectrum components as a series of RF pulses of different nominal center frequencies.

The output-pulse time-ordering, relative to the start of the chirp period, is linearly related, in reverse order, to the frequency of the input component signals. Basic energy detection on either channel permits determination of relative signals frequency, amplitude, time-of-intercept (TOI), and limited modulation analysis from one chirp period to another.

For the phase interferometer implementation, the undetected RF signal pulses are passed to a linear, wideband, phase discriminator or correlator.[1] The design of this phase discriminator/correlator is quite standard, and such devices are readily available. One channel of the discriminator is used as the reference, the other as the signal input. The output in-phase (ΔI) and quadrature (ΔQ) signals are video (V) detected. The relative amplitude and polarity of the detected Δ I and Δ Q signal pulses are a complex vector representation of the phase difference between the component input signals being processed. The phase difference angle is determined by computing the arc tan (Δ Q/Δ I). This angle computation can be easily implemented, using a read-only memory (ROM) look-up table procedure requiring no actual mathematical divisions. The phase shifters, $\Delta \phi_1$ and $\Delta \phi_2$, shown in Fig. 1, are not essential to the operation of the interferometer processor. They are used primarily to balance out fixed phase differences between the processor channels and to establish a reference for the calibration process.

PROTOTYPE PROCESSOR AND TEST RESULTS

In order to verify the compressive interferometer processing concept a moderate performance prototype was fabricated at ERADCOM. Figure 2 is a photograph of the brassboard prototype processor used to obtain the experimental data presented in this section. No particular attempt was made to package the processor in a compact form. Additionally, except for the design of the SAW chirp filters[2], all components and amplifiers used in the construction of the prototype were commercial off-the-shelf items, with no special matching or tolerance control. The SAW filters, however, required tight control of dispersion and propagation loss factors. The SAW lines used in this prototype were not optimized for full bandwidth operation. Despite this lack of system optimization, the results obtained were surprisingly good.

The original processor design called for a 10 MHz processing bandwidth with a 200 KHz signal resolution capability. These specifications were selected primarily on the basis of fabrication convenience[3] rather than to meet a specific requirement. Commercial state-of-the-art for PCL's of the type required for this processor can readily provide lines having 500 MHz bandwidth and resolution of 2 MHz. An "in-line" dispersive filter design, was used to implement the chirp filters on an ST-X quartz substrate.

Figure 3 illustrates the processor's simultaneous-signal phase-resolving capability. Two signals, having different frequencies and simulated AOA

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(phase off-sets), were simultaneously injected into the processor. Figure 3a illustrates widely spaced signals, and Figure 3b illustrates closely spaced signals.

Figure 4 illustrates the measured tracking of the chirp transform filters, PCL 2, used in the processor. The mean phase imbalance versus the frequency variation of the channels can be removed using calibration techniques. The residual error appears to be approximately $\pm 2^{0}$, which is satisfactory for this application.

In figure 5, the variation of measured phase versus input phase offset as a function of frequency is shown. The measured phase angles were computed by finding the arc tan of the ratio of Δ Q to Δ I. Some of the phase measurement variations shown in these curves are the result of phase discriminator nonlinearities. Additional errors are also introduced by the measurement phase shifters. The use of a better quality discriminator should improve the linearity and tighten the separation of these curves. In any case, these curves are repeatable and form the basis for a ROM phase measurement correction table. The corrected phase-angle-estimate is selected by using measured phase and frequency data as address information for a ROM look-up table.

CONCLUSION AND DISCUSSION

Table 1 compares the SAW Compressive Interferometer techniques with various other DF subsystem implementations. As is evident from this table, there is no single DF measurement system implementation which performs optimally in all categories of system performance. The presented technique, however, does represent a good compromise solution to the problem of performing DF measurement on multiple simultaneous signals. This technique is particularly well suited to applications requiring wideband intercept operation combined with a need for both good system sensitivity and multiple signal dynamic range. Current state of the technology can provide a compact implementation of this processor featuring 500 MHz of intercept bandwidth; 2 MHz of frequency resolution; 60 dB of single signal dynamic range, and multiple signal dynamic ranges of 40 dB or greater. Such potential performance capability makes this technique an attractive alternate solution for many EW applications.

REFERENCES

1. S.J. Robinson, "Broadband Microwave Discriminators," PGMT Transactions, Vol 12, Mar 64.

2. W. J. Skudera, and H. M. Gerard, "Some Practical Design Considerations of Dispersive Surface Wave Filters," Proceedings of 27th Annual Frequency Control Symposium, pp 253-261, Jun 73.

3. W. Skudera, and G. LeMeune, "Acoustic Surface Wave Fabrication Techniques and Results," ECOM Tech Rept 4333, Fort Monmouth, NJ 07703, Aug 75.

TABLE 1

RCVR TECH	SENSITIVITY	DYNAMIC RANGE SINGLE SIG	DYNAMIC RANGE MULT SIG	BANDWIDTH	FREQ MEAS ACC	DF TECH	DF ACCURACY
Crystal Video	P	P	N	WB	N	AC	P
Superhet	H	H	N	NB	H	PC	H
IFM/DISC	M/H	M	N	WB	M/H	PC	H
Channelized	M/H	M/H	M	WB	M/H	AC	M
Compressive	H	M/H	M	WB	M/H	AC	M
Optical	H	M/H	P	WB	H	AC/TG	M
SAW Compressive Interferometer	H	M/H	M	WB	M/H	PC	H

P-Poor
M-Moderate
H-High
N-None
WB-Wideband
NB-Narrowband

*Best DF Tech
AC-Amp Comp
PC-Phase Comp
TG-Time Gradient

TABLE 1.

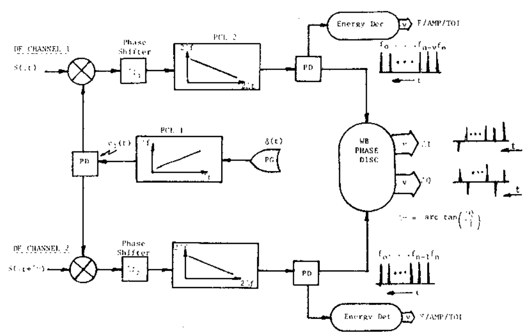

FIG. 1. COMPRESSIVE INTERFEROMETER BLOCK DIAGRAM

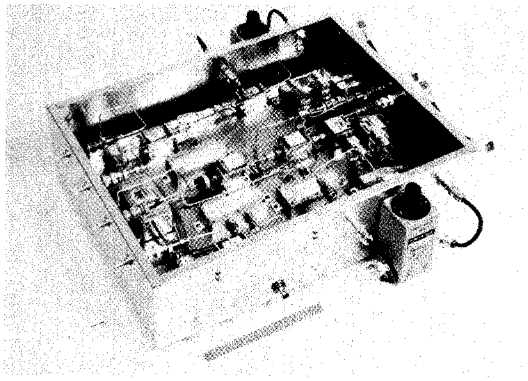

FIG. 2. PROTOTYPE SAW COMPRESSIVE INTERFEROMETER

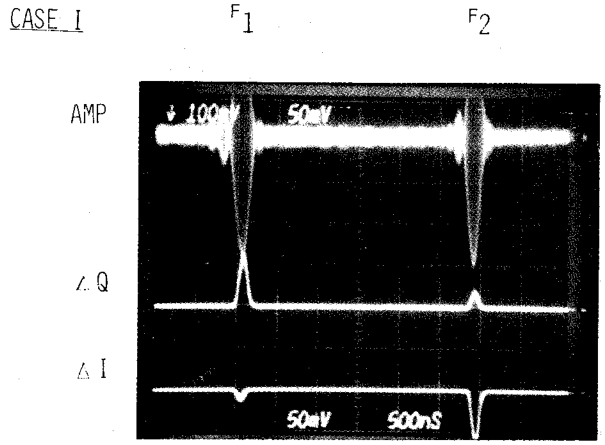

FIG. 3. SIMULTANEOUS SIGNAL PHASE MEASUREMENT
3a. TWO SIGNALS WIDE SEPARATION

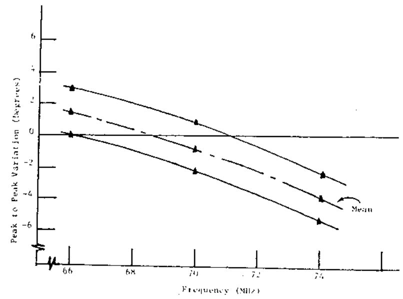

FIG. 4. CHANNEL TRACK IMBALANCE

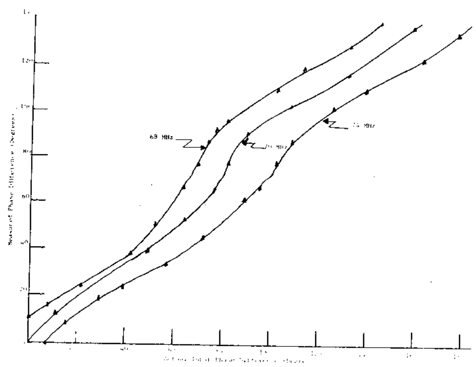

FIG. 5. MEASURED PHASE VS INPUT PHASE DIFFERENCE

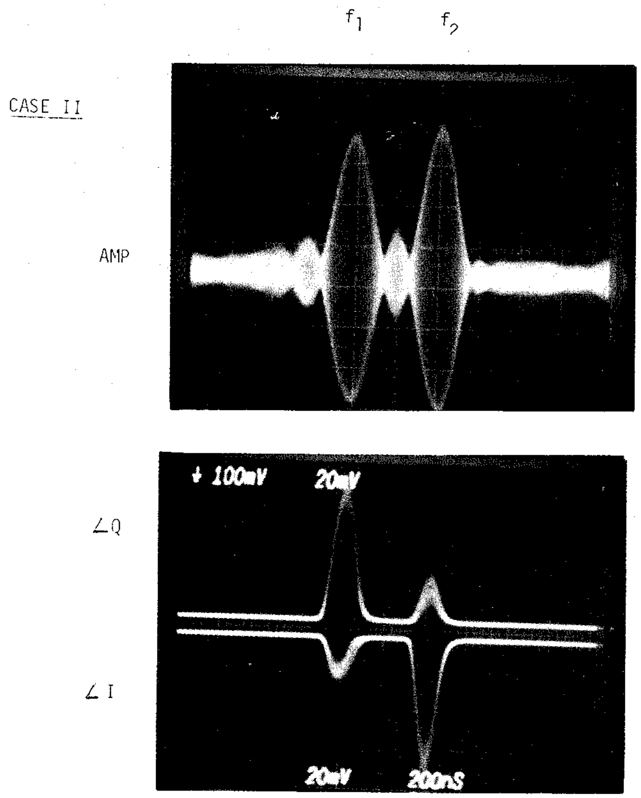

FIG. 3 SIMULTANEOUS SIGNAL PHASE MEASUREMENT
FIG. 3B. TWO ADJACENT SIGNALS