Code - Modulated Beamforming for Mobile Distributed Array

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Abstract— **We propose a novel Code - Modulated Beamforming (COMB) technique for swarm array (SA) communication with its destination. RF signal at each mobile element is coded with independent random code before sent out. At the destination, the signals are received with an UWB antenna and a single receiver. After decoding and demultiplexing, the recovered digitized baseband multi-channel signals are sent to beamformer for array processing. The advantages of the proposed COMB technique are blind search and robustness against mobile element positioning error and vibration.**

I. INTRODUCTION

Swarm of distributed platforms offers adaptability and reconfigurability in array formation or network connection through coordinated spatial placements of the platforms and software update. In fact, each mobile platform in the swarm can operate in a similar fashion to a SAR system, and when all platforms collaboratively perform sensing, the cross-range resolution is enhanced, the sensing time is shortened, and a wide region-of-interest (ROI) is covered. The SA system, will integrate sensing and communication based on a modular array that comprises of N drones, with a reconfigurable geometry that cognitively adapts to the sensing requirements, the intrinsic characteristics of the sensed ROI, communication range and bandwidth. Through collaborative sensing and processing this system is N times faster than conventional SAR. In addition, through coherent distributed beamforming its communication range is extended due to N^2 -fold power gain. [1-4].

We have recently developed a novel Code - modulated Beamforming (COMB) technique for swarm array (SA) communicating. It can cover a 360° field of view and digitally beamform through a wireless network. The SA elements only act as transmitters or repeaters. Since the system is precisely synchronized, SA element position error will not affect the beamforming. COMB is designed for SA, but may also be applied to fixed sparse array.

II. CODE MODULATED BEAMFORMING

COMB system diagram is illustrated in Fig. 1. N precisely synchronized mobile platforms send coded data to the destination wirelessly. We assume that the signals from the mobile elements to the receiver have line-of-sight (LOS) propagation links. We ignore multipath, interference, and Doppler frequency shift. The received signal is filtered to avoid aliasing, digitized, deorrelated and demultiplexed. After recovering the channel signals at baseband, beamforming may be performed.

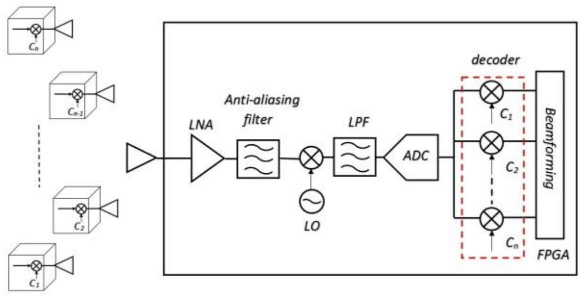

Fig. 1. CBS system diagram.

Although we spread the original signal with orthogonal code, and decoded to recovery the channel signals for beamforming just like what were done in the on-site-coding beamforming [5] and code-modulated path sharing approaches [6], However our purpose is not only for RF hardware reduction, but also real time on-site calibration before beamforming. Also COMB seems close to the wireless networked beamforming [7], array element signals are wirelessly sent to beamformer for process. But in [7], the elements have predefined fixed positions. No encoding and decoding are used for on-site calibration for mobile distributed array. Our approach is fundamentally different from SKA Low (Square Kilometre Array) correlator and beamformer [8], since we don't perform time delay at the antenna site, greatly reduces platform sensing and computation burden for precise localization, calibration and correlation computing. Moreover, the presented system provides significant reduction in overall system cost, hardware footprint, RF error and power consumption by using a single receiver and a single LO at the destination.

Fig. 2 shows performance curves for the COMB beamformer with different number of mobile platforms. It is assumed that the channel characteristics and the delays are known at the receiver. Each antenna's signal is encoded using a code having a spreading factor 32 that shows chip period is much smaller than symbol period and the bandwidth of the spread-spectrum signal is much larger than the bandwidth of the original signal. Monte Carlo simulation with 20 run is used in the simulation. The recovered signal at the beamformer output is compared with the normalized original signal transmitted by the SA elements as shown in Fig. 3.

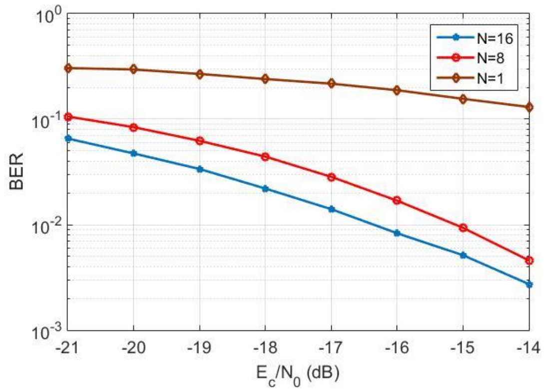

Fig. 2. BER performance for different number of drones.

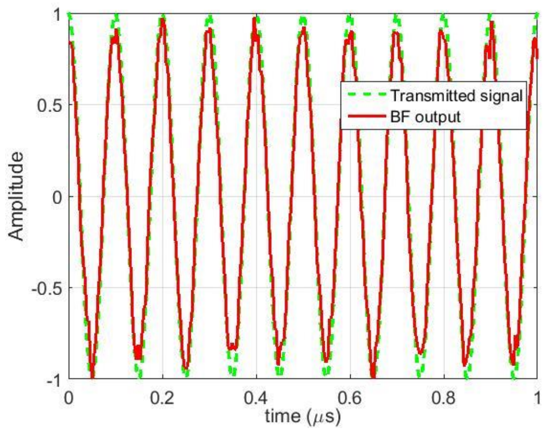

Fig. 3. Recovered signal at the 16-element COMB output**.**

III. Hardware Implementation Cosideration

A testbed is designed as shown in Fig. 4. The baseband analog signal of bandwidth B from an arbitrary waveform generator (Tektronic AWG520) is modulated with a random orthogonal spread spectrum code $c_i(t)$ of length Lc and chip rate R_C. The bandwidth of resulting spread signal is equal to the chip rate. Subsequently, all received signals from the *4*-antenna elements are multiplexed and send to a a high speed Gage CSE8482 digitizer for processing. The Gage digitizer with a high sample rate at 25 MS/s and 16 bits resolution. ADC bandwidth (20MHz-100MHz) is more than twice the spread signal bandwidth to satisfy the Nyquist criterion. The Gage output signal is decorrelated with the same spreading codes $c_i(t)$. The channel signal assocaite with each platform is then recovered in digital form. With known time delay for each channel during the correlation process, the channel data are shifted and summed up to recover the original signal sent from the platforms.

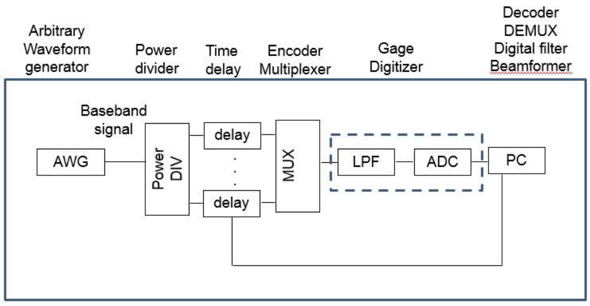

Fig. 4. COMB testbed set up.

IV. Conclusions

We have presented a novel COMB technique for SA communications. Comparing with the state of art mobile distributed array beamforming technologies, COMB has several obvious advantages: 1) All the elements send channel signals wirelessly to the destination for beamforming, thus greatly reduces the complexity, power consumption and load for the drones. 2) Since the SA system is synchronized through GPS based lock with destination at the tie accuracy below 1ms, time delay can be accurately obtained all the elements. There will be no needs for real time array calibration and for precise knowledge of element positions. 3) COMB has flexibility for reconfiguration, adaptability to the operational environment, and the ability to upgrade the system performance via software. The main technological challenge in COMB is limited data rate. The ADC sampling rate is set to be at or above the Nyquist rate with respect to the modulation bandwidth B and is given by $f_s \geq B \times N$. With the up limit of the ADC speed, the number of the array will be limited for specific modulation bandwidth.

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