Below are excerpts from US Patent No. 12363640 B1, entitled "Ad Hoc RF Network Structures and Methods" issued by United States Patent and Trademarks Office (USPTO)

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ABSTRACT

Structures and integration of circuits and sub-systems for ad-hoc, wide-bandwidth, radio frequency (RF) networking are disclosed. Networks may have both mobile and stationary Users. Disclosed are structures and methods for User network access via time, space, code and frequency domain sharing. A physical layer of network architecture comprises novel encoders, modulators, demodulators and phase-based beamformers. Embodiments may function as integrated systems providing communication capabilities for future networks such as 6th Generation (6G). Enabled operational capabilities may include low-latency, ad-hoc network access. Deployment concepts may include coupling to platform-specific User Equipment, thereby allowing diverse User form-factors and functions. Small, low-power form-factors are made viable by integration of memristor technology into novel structures and circuits.

BACKGROUND OF THE INVENTION

Wireless communication has spanned several generations of systems. These included earlier Time Domain Multiplexed (TDM) and Frequency Domain Multiplexed

(FDM) systems. These were followed by more complex multi-access schemes, such as Code Domain Multiple Access (CDMA) for 3G networks, and Orthogonal Frequency Domain Multiplexing (OFDM) in 4G and 5G networks. The latter systems require sophisticated coordination through a network of base stations. They have successfully serviced the growing markets for personal communications for several years. However the Internet-of-Things (IoT), sophisticated machine-to-machine (M2M) communications, and expanded personal use will require new wireless networks. Although certain emerging 6G techniques (such as mmw carriers) may facilitate future networks, many basic challenges exist. Operational issues will include low-latency, ad hoc connectivity among multiple Users. This may be fundamentally at odds with traditional paradigms of network coordination through a base station or centralized controller. Also, the evolution of RF systems to higher carrier frequencies and wider bandwidths may impose extreme computational requirements with limited space and power resources.

SUMMARY OF THE INVENTION

The present disclosure provides certain illustrations, examples and descriptions. These are not intended to be exhaustive or limiting of embodiments of the invention. Given the present disclosure, it will be apparent to one skilled in the art that variations or modifications of the embodiments described herein may be possible. It is intended that all such variations and modifications fall within the scope of the present invention.

Emerging 6G technologies (such as mmw carriers and high density antenna arrays) may facilitate future wideband networks, but many basic challenges exist. Issues regarding latency and ad hoc network access pose major operational difficulties. Also, the inherent nature of signals creates challenges such as “Doppler Spreading” for mobile Users, and elevated Peak-to-Average Power Ratio (PAPR) in OFDM type signals.

Accordingly, the present invention may integrate circuits and sub-systems to support ad hoc, low-latency, wideband RF networks. Advantageous methods and embodiments of the invention may allow User network access via simultaneous temporal,

spatial and code domain sharing. This includes the use of pulse signals for temporal domain sharing, beamforming for spatial domain sharing, and the embedding of User identification information into pulses for code domain sharing.

Embodiments characterized by integration of novel analog and digital circuits may provide desired operational capabilities for future 6th Generation (6G) networks. This may include low-latency, ad hoc network access. Deployment concepts of the invention includes coupling to platform-specific User equipment, thereby supporting various types of User forms and functions. Some circuits of the invention might be combined onto a single monolithic device or "die" as disclosed. In this way the circuits' physical impact upon a User may be minimized.

Methods and Signal Processing Chains

This Subsection Deleted

Advantages and Utility

Extended "latency" is a critical concern for future 6G networks. For instance, procedures of resource allocation and beam management may require tens of milliseconds of overhead in 5G systems. Latency may arise from the centralized nature of traditional network control. By contrast, the disclosure is directed toward multi-User network access on an ad hoc basis, potentially reducing latencies from orders of milliseconds to microseconds.

"Ad hoc operation" may be an expectation of future 6G systems not readily supported with traditional networks. This is due to the centralized control structure of conventional approaches. Disclosed herein are ways to discriminate among RF "pulse trains" of multiple Users on the basis of multiple signal characteristics. These may include a pulse-rate-interval (PRI), a pulse direction-of-arrival (DOA), User identification code, and pulse frequency structure. This allows Users to join a network in spontaneous

fashion without mutual coordination or centralized scheduling activities. The approach has analogies in the natural and man-made worlds. In the former, bats effectively use acoustic pulse signals in navigation. In the latter, multiple pulse-radar systems may operate independently and simultaneously. Although these are examples of "sensing" systems, they illustrate the viability of signal discrimination (and tracking) using a multi-domain pulse signal identification approach.

"Real-time computing" Embodiments described herein may include unique signal generators, processors and beamformers. These may employ both digital signal processing (DSP) and "discrete-time analog processing". The latter includes the novel use of "memristor" technology to address computational challenges of extremely wide-band RF systems. Memristor technology has been seriously researched in the context of "in-memory" computing for applications such as neural networks. However, disclosed herein is novel application of memristor technology to network communications. This includes use of the technology for electronically steered, phase-based beamforming. This allows rapid and efficient sharing of the spatial domain among multiple Users, while minimizing the cost and complexity of precision beamforming.

"Doppler spreading" is a fundamental problem in high-frequency, mobile, wireless OFDM communications systems. It is rooted in the physics of RF signal transmission. It causes undesired frequency shifts of the "subcarriers" of wide 5G OFDM "symbol" waveforms. The problem is exacerbated by both higher operating frequencies and high relative velocities of Users. As such, it can be of even greater concern for 6G networks. However the disclosure does not require the wide "time domain" symbols of 5G waveforms, but may instead may use narrow "pulses". Thus for the same operating bandwidth and carrier frequencies, a much wider frequency spacing of subcarriers results in proportionally smaller effects due to Doppler spreading.

Large "peak-to-average-power-ratios" (PAPR) is an inherent issue with conventional OFDM systems having very wide symbols. Having a mathematical basis in the Central Limit Theorem, large peaks in the symbol power levels can occur due to the

random superposition of many subcarriers. However an advantage of the disclosure's narrow pulse widths (as compared to wide OFDM symbols) is naturally lower PAPR levels. This is due to fewer subcarriers in a short pulse as opposed to a long symbol. This advantage may either simplify power amplifier design, and/or increase propagation range of the pulse signals (by increasing average transmitted power of the pulse signals).

"Squint" is a well-known and undesired side-effect of phase-controlled beamforming. The phenomenon can greatly degrade channel capacity, especially for wide-band signals. Certain beamforming structures and methods disclosed herein may be useful in mitigating the effects of squint.

Terminology and Definitions

Multiple Subsections of the SUMMARY OF THE INVENTION Section are deleted below. The complete Section and remainder of the Patent document may be found at the USPTO website.

Filename: PN1 Excerpts-1