JOSEPHSON JUNCTION DIGITAL TO ANALOG CONVERTER FOR ACCURATE AC WAVEFORM SYNTHESIS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to digital to analog signal converters and more particularly to a low phase noise digital to analog converter utilizing Josephson junctions in connection with programmable voltage standards for metrologically accurate waveform synthesis and cryogenic radar systems.

2. Description of Related Art

Josephson junctions are well known devices consisting of two superconductors separated by a thin film of dielectric material or normal metal. Such devices are typically comprised of superconducting layers of Nb separated by Al_2O_3 or superconducting layers of $YBa_2Cu_3O_7$ separated by Co doped $YBa_2Cu_3O_7$ and produce quantum mechanically accurate voltage pulses generated as a result of phase slips in the quantum wave function of the superconductor system. This is accomplished by exploiting the now well known Josephson effect which is characterized by absolutely repeatable constant voltage steps in the junction's current-voltage characteristic. For a detailed treatment of Josephson junctions, one can refer to "Fundamentals Of Giaever And Josephson Tunneling", Y. Bruynseraede et al, *The New Superconducting Electronics*, ed. by Harold Weinstock and Richard W. Ralston, Kluwer Academic Publishers, 1993, pp. 1–28.

In metrology applications, primary standards for AC voltage presently rely on thermal voltage converters that compare the heating effect of AC and DC inputs. Direct waveform synthesis from an accurate AC voltage source would provide the first independent check of the accuracy of thermal voltage converters and change the fundamental method of AC metrology from detector-based to source-based calibrations. The Josephson D/A converter in accordance with the present invention will be the first such programmable voltage standard source.

In radar systems implemented with RF signal generators employing cryogenic techniques, low phase noise RF signals can be obtained from cooled dielectric resonators, e.g. sapphire resonators. However, the signal generated is a continuous wave signal of a single frequency. In order to enable such a radar system to provide range compression, it becomes necessary to produce low phase-noise carrier frequencies which are swept both linearly and non-linearly during the transmitted pulse. This is known to those skilled in the art as "chirp". Accordingly, the present invention also pertains to cryogenic radar systems.

SUMMARY

It is an object of the present invention, therefore, to provide an improvement in the generation of time-dependent waveforms.

It is a further object of the invention to provide a waveform generator for programmable voltage standards and radar systems which include a digital to analog signal converter wherein a digital data stream is converted to low noise analog voltages.

It is another object of the invention to provide a digital to analog signal converter wherein the analog signal has quantum mechanically accurate time-dependent voltages.

The foregoing and other objects are achieved by a method and apparatus including a waveform generator comprising means for generating a digital data stream having a predetermined frequency spectrum incorporated therein, a plurality of series coupled Josephson junctions coupled to and excited by the digital data stream to provide a digital data stream output having voltage pulses with quantum mechanically accurate time-integral, and a low pass analog signal filter coupled to the pulses for retrieving analog signals. For metrology applications, the output of the low pass filter is the signal of interest because it has a calculable time-dependent voltage. For radar applications, a low phase-noise local oscillator of a fixed frequency, a mixer responsive to the respective outputs of the local oscillator, and the low pass filter is used for generating low phase-noise RF chirp signals for use in generating transmit pulses for the radar system and which provides enhanced detection of targets in "clutter".

Further scope of applicability of the present invention will become apparent from the detailed description of the invention provided hereinafter. It should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are provided by way of illustration only, since various changes, alterations and modifications coming within the spirit and scope of the invention will become apparent to those skilled in the art from the detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood when considered together with the accompanying drawings which are provided by way of illustration only and thus are not limitative of the present invention, and wherein:

FIG. **1** is a block diagram illustrative of one preferred embodiment of the subject invention and where the mixer is only relevant to a radar application; and

FIG. **2** is a block diagram illustrative of a second preferred embodiment of the subject invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention is based upon the ability of Josephson junctions to produce an output pulse of a single flux quantum ϕ_0 when an excitation pulse causes its critical current I_c to be exceeded. This mechanism is well known in the art, having been discovered in 1962 by B. D. Josephson.

The Josephson effect manifests itself as a time-dependent voltage across the junction consisting of quantized voltage pulses with a time-integral equal to the flux quantum unit $\Phi_0=h/2e$, where h is Planck's constant and e is the elementary charge. When a digital pulse train with an appropriate amplitude is applied across one or more Josephson junctions, each input current pulse generates a corresponding output voltage pulse across each junction and the time integral of each voltage pulse is perfectly quantized. This phenomenon is used in the subject invention to generate time-dependent voltage waveforms with accuracy not currently obtainable with other types of technology.

Referring now to FIG. **1**, an essential component of the invention is the Josephson quantizer **10**, which is typically comprised of a plurality of series connected Josephson junctions $J_1, J_2, \ldots J_{n-1}, J_n$. The quantizer **10** is fed a binary digital data stream **18** having a desired spectrum implemented in its digital pattern. To prevent reflections and ensure uniform transmission of the digital data stream to each junction, the series array is embedded in a high impedance transmission line that is terminated by an impedance matched resistor **20**.