DESIGN AND PRODUCTION OF A LOW-POWER LOW-COST HIGH FREQUENCY DOPPLER RADIO SCATTEROMETER (HFDRS) FOR COASTAL ZONE OCEANOGRAPHY

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A new beam-forming HFDRS a.k.a. Doppler Radar has been designed, maximizing commercial-off-the-shelf (COTS) components thus minimizing overall cost, minimizing power consumption thus enabling solar/wind operation in remote areas. For 8 channels, components cost less than k$30 and six man-weeks suffice for assembly, testing and calibration. Power consumption is 300W full duty. It uses frequency-ramped continuous wave signals, and phased-array transmissions to decouple direct path to receivers. Fan-less operation of critical components avoids 60Hz inter-modulation. Five sub-assemblies are controlled by a Linux server: (i) COTS direct digital synthesis of transmit and orthogonal local oscillator signals, derived from a ultra-low phase noise oven-controlled crystal; (ii) COTS 50-W MOSFET power amplifier; (iii) lambda/20 compact active antenna monopoles with embedded out-of-band rejection filters; (iv) analog homodyne receivers based on complex demodulation by double-balanced mixers; (v) COTS 24-bit analog-to-digital sigma-delta conversion with 512 oversampling and digital low-pass filter. At 16 MHz, 20 W transmit, 10 min averaging, range of 120 km is achieved. Twenty units were built, and are being deployed in Hawai'i, Mexico and the Philippines; one is on display at booth E8.

Objectives:

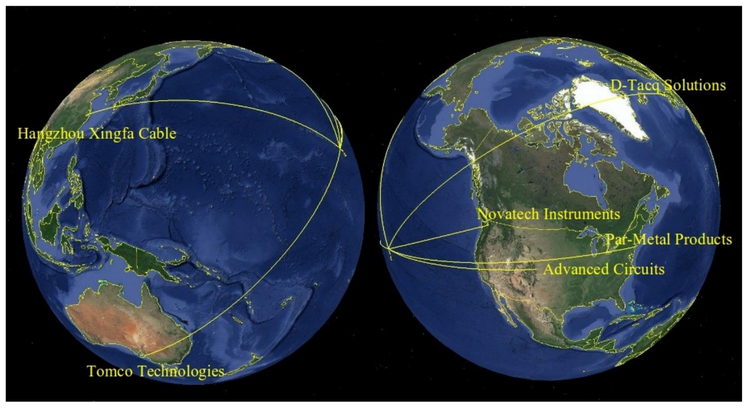
- maximize commercial-off-the-shelf components (COTS)
- minimize overall cost (non-profit non-subsidized)
  - $64,000 16-channels 50 W RF (beam-forming)
  - $48,000 8-channels 50 W RF (beam-forming)
  - $24,000 4-channels 5 W RF (direction finding)
- readily scalable to arbitrary number of channels
  - $2,000/channel
- minimize power consumption
  - 320 W AC for 16-channel 50 W RF (continuous)
  - 80 W AC for 4-channel 5 W RF (continuous)
- solar/wind operation enabled
- fan-less operation of critical components to avoid 50/60Hz inter-modulation

System specifications:

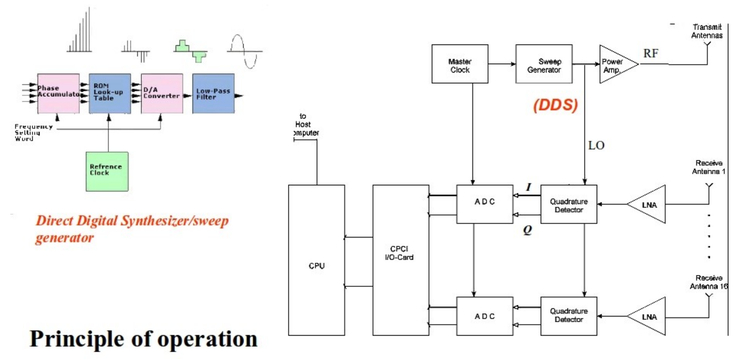
Modulation	FMCW frequency-ramped linear chirp
Operating Frequency	3 MHz to 30 MHz
Transmitted RF-Power	5-50 Watts, beam-formed towards ocean (+ 6 dB)
Range	typ. 120 km/ 65 NM @ 16 MHz
Range Resolution	depends on bandwidth c/2B 1.5 km @ 100 kHz, 150 m @1 MHz
Azimuthal Resolution	- beam-forming arbitrary array(8 to 32 antennas) - direction-finding square array
Systems built	22
Deployed	Hawaii (5), Philippines (2), Mexico (3), France (1)

System overview:

- sub-assemblies controlled by Linux server
- ultra-low phase noise oven-controlled crystal for synchronous signal synthesis and A/D conversion (VECTRON OXCO)
- direct digital synthesis of transmit and orthogonal local oscillator signals (ANALOG DEVICES DDS/NOVATECH)
- 50 W RF power amplifier (TOMCO)
- λ/8 passive or 1.5 W active (no PA) transmit monopoles (UH)
- λ/20 active receive antenna monopoles with out-of-band rejection filters (UH/DLWA)
- complex demodulation by double-balanced mixers, homodyne translation of HF spectrum to audio band (UH)
- 24-bit analog-to-digital sigma-delta conversion with 512-oversampling and digital low-pass filter (DTACQ)



The supply chain... and our industrial partners



Direct Digital Synthesizer/sweep generator

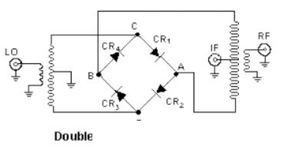
Principle of operation

Double-Balanced Mixer/quadrature detector:

I: 2 sin x sin y = cos (x-y) – cos (x+y)

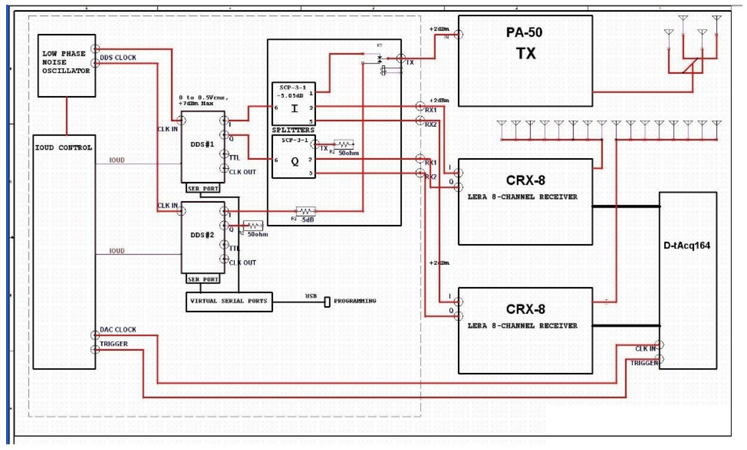
Q: 2 sin x cos y = sin (x-y) + sin (x+y)

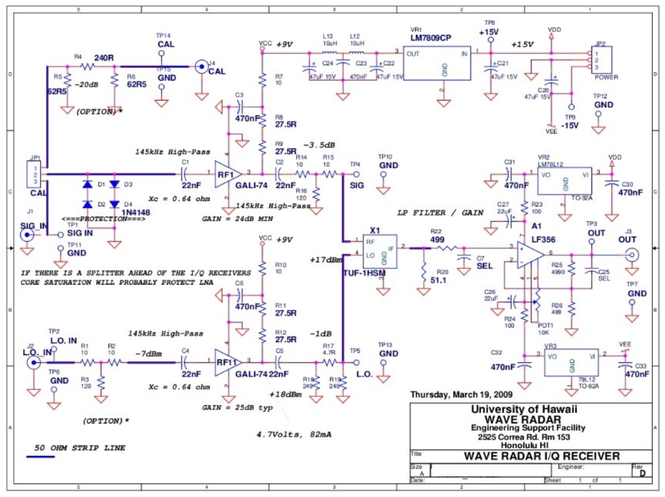
if x= (ω + Δ ω) t **and** y = ω t **then** x-y = Δ ω t



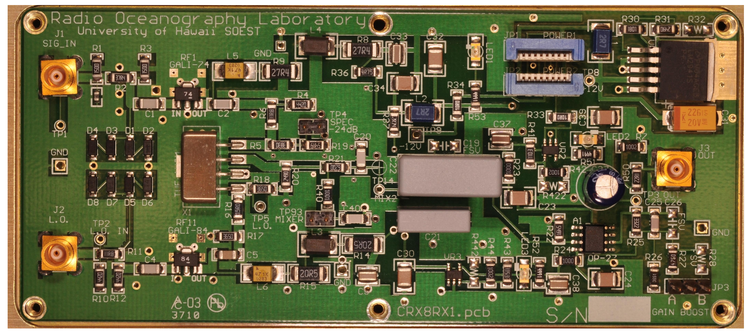
Double

Block diagram





Critical UH-designed circuit: complex demodulator (600 built)



Thank you!

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Software solutions:

- Output simple binary files of A/D converter antenna signals
- Simple to process directly in matlab, m-files provided
- Python scripts for spectra, currents under development
- Simple import to all common processing packages:
  - Neptune/Seaview Sensing currents/wave/wind
  - Gurgel/Helzel WERA currents/wave/wind
  - LSET/Broche/Barbin currents

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SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY
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