6
SDR remote transceivers to match the base arrays, and the ipPNT* functions

* GPS- independent precise position, navigation & timing

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http://www.rtl-sdr.com/passive-radar-dual-coherent-channel-rtl-sdr/

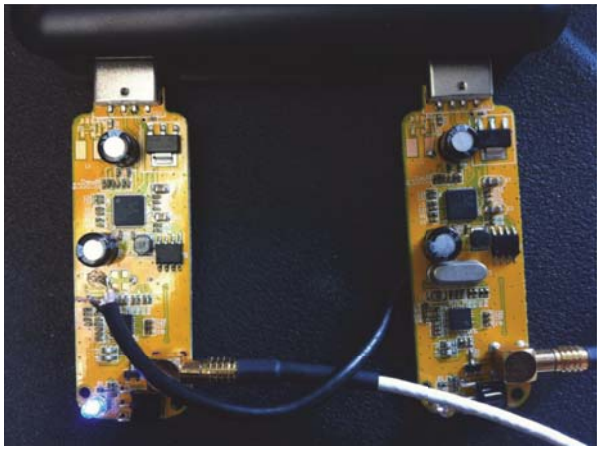
RTL-SDR (RTL2832U) and software defined radio news and projects. Also featuring Airspy, HackRF, FCD, SDRplay and more.

SEPTEMBER 27, 2013 PASSIVE RADAR WITH A DUAL COHERENT CHANNEL RTL-SDR

Juha Vierinen from the Kilpisjarvi Atmospheric Imaging Receiver Array has been working on a Dual Coherent Channel RTL-SDR modification.

VIDEO here: http://www.youtube.com/watch?v=6Wiv8Dwi-kA [This popular-radio-tech website article is based on the following:]

http://kaira.sgo.fi/2013/09/16-dual-channel-coherent-digital.html



Thursday, 26 September 2013

$16 dual-channel coherent digital receiver

I have been playing around with the cool RTL dongles (more on rtl-sdr dongles on superkuh's web page or rtl-sdr.com) that you can buy on e-bay for about US$8 (including shipping). These are very capable 8-bit digital receivers that have up to 2.4 MHz bandwidth and can tune anywhere between 24 MHz and 1850 MHz.

I recently came up with a trivial hack to build a receiver with multiple coherent channels using the RTL dongles....by unsoldering the quartz clock on the slave units and cable the clock from the master RTL dongle to the input of the buffer amplifier (Xtal_in) in the slave units (I've attached...pictures).

I originally drove the master crystal with both dongles, which also worked. However, Ian Buckley pointed out to me that a more typical way of doing this is feeding the signal into Xtal_In (in the pictures ...). So I tried that too, and it also worked. I'm still not sure what the optimal setup is, as there is no schema for the dongle, but both methods I've tried so far have worked in practice.

This has some implications for low cost geophysical instruments. It will be possible to use this receiver for the 150/400 MHz beacon satellite receiver, as this only requires that the receivers have clocks that are locked with each other. Interferometry and passive radar are other application[s]... With more than two locked channels, applications such as imaging start to become possible.

I've made some relative phase noise measurements, and the systems don't have detectable sample drift over two hours, and their relative phase is also pretty stable.

...I found this nice usb hub, which I'm going to use to hopefully get a 7 channel coherent rtl system. ....Update: Apparently three dongles will also run fine from one master clock.

Hub with the right usb port orientation for rtl dongles

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References 1: Re remote radio devices: example of advancements

DekTec Debuts Pocket All-band Modulator

DekTec Debuts Pocket All-band Modulator

The DekTec DTU-315 is powered via a USB-3 interface, which also provides a control and data interface. F and BNC cable assemblies are included with the product.

- Fully agile from 36 to 2150MHz, covering VHF, UHF and L-band
- Modulation bandwidth up to 70MHz
- Supports all constellations and modulation modes for each supported standard
- Digital channel simulator option including multipath echo and AWGN

The modulator is used with DekTec's StreamXpress™ for easy generation of RF test signals, or you can write your own application using the free Windows and Linux SDK (DTAPI).

Applications for the pocket modulator include:

- RF test generator in your R&D lab or factory for developing, qualifying or repairing any equipment with a DTV antenna input;
- a portable demo set for TV receivers, easy to carry to customer demos, trade shows, etc;
- or for TV transmission and distribution using modulated signals in retail, hotels, hospitals, etc.

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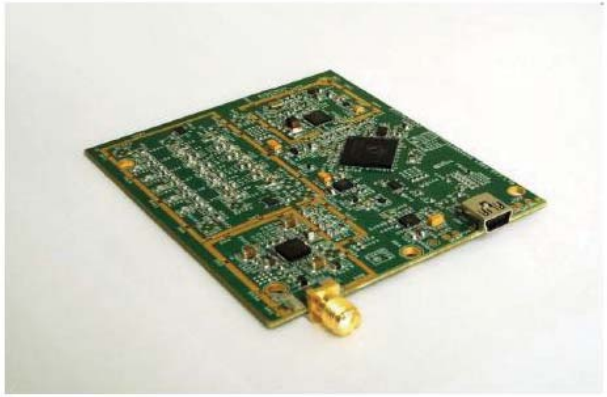
References 1: Re remote radio devices: example of advancements

SLM901UU 1-CH DTV MODULATOR

Saankhya Labs

DESCRIPTION

SLM901xx module is the World's First Software Defined Single Channel Digital TV Modulator solution to support Worldwide Digital Terrestrial and Cable TV Standards. Based on Saankhya Labs SL900x Modulator IC, the SLM901UU USB module supports multiple modulation standards and custom modulation through software update, without consuming any computation cycles from host CPU.



STANDARDS SUPPORTED

Standard	Bandwidth	Modulation	Data Rate
ATSC	6 MHz	8-VSB	19 Mbps
ISDBT	6 MHz	OFDM 1-seg/13-seg	23 Mbps
DVB-T	8 MHz	OFDM	30 Mbps
QAM/DVB-C	6/8 MHz	16/64/256 QAM	40 Mbps
Custom	Program for Secure Communication		

APPLICATIONS

- Video distribution Head-end / Hospitality TV, SMATV
- Digital Signage, Trade Shows, Shopping complexes
- Drone HD-Video Wireless Transmitter
- Custom Modulation for Secure content distribution
- Surveillance, remote monitoring and control

FEATURES

- Frequency Range: 48 - 860 MHz (VHF/UHF)
- Configurable Bandwidth : 6, 7 or 8 MHz
- Modulation: 8VSB, BPSK, QPSK, OFDM, 16-256QAM
- Output Level: -20 dBm to 0 dBm (1mW)
- Carrier Suppression: > 35 dB
- Adjacent Channel Leakage Ratio (ACLR) : > 40 dBc
- Modulation Error Ratio (MER) > 40dB
- Power consumption < 1.9W (5V, 375mA)
- Power supply – derived from USB
- Input Connector: USB Mini-B
- Output Connector:50 ohm F-Type Female (SMA)
- Board Dimensions (approx.): 2.77" x 3.26"
- Board Weight: <100g
- Linux/Windows/Android Application Software

ORDERING INFORMATION

Part Number: SLM901UU

Availability: Now

Unit Price: $350

Contact: info@saankhyalabs.com

Comment.

We believe this can be adjusted with modest NRE to operate from ~ 30 MHz to 930 MHz, covering licenses, and in bandwidth down to 100 kHz or thereabouts.

Competitors of this company (as to at least core chips) can do the above, as well, e.g., Lime Microsystems - see next.

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References 1: Re remote radio devices: example of advancements

Lime microsystems

HOME | PRODUCTS | APPLICATIONS | OPEN SOURCE | NEWS | COMPANY | RESOURCES | CONTACT

Overview | Features summary | Resources | Support

The LMS7002M is Lime's second-generation field programmable RF (FPRF) transceiver IC with extended functionality to cover a greater range of frequencies and applications.

The device uses state of the art transceiver design in CMOS technology to significantly reduce cost and power consumption. It integrates a dual transceiver architecture to support 2x2 MIMO along with on-chip digital signal processing functions. The LMS7002M can run on any mobile communications and wireless standard – including all 2G, 3G and 4G variants and WiFi – both licensed and unlicensed.

The LMS7002M is ideal for a wide range of consumer and professional applications, including:

- Small cell communications equipment

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- M2M networks
- Broadband wireless
- Netbooks and tablet PCs
- Test equipment
- Open source radio
- Military
- SDR
- Cognitive radio

Lime's proven FPRF technology has been used by private companies, government and military organisations to create a myriad of wireless broadband technologies, from whitespace radios to disaster relief networks to communications infrastructure devices.

Highlights

Configurability

The LMS7002M has a continuous operation spectrum of 100khz to 3.8GHz, and is software configured to operate up to 120MHz RF bandwidth.

The device can be configured to use the 2G, 3G and 4G standards – including all TDD / FDD variants – and a host of additional standards, including WiFi.

Single chip MIMO (2×2)

To enable advanced networks to be created, the chip features a dual transceiver architecture. It integrates 12-bit ADCs and DACs, LNAs, filters and mixers to provide two transmit and receive paths, enabling a true single-chip (2×2) MIMO operation. The transceiver's enhanced capability features, such as an on-chip microcontroller, further simplify its calibration and installation. Furthermore, its extensive on-chip DSP has been programmed to enhance functionality and performance.

Comments. This covers all of 35 MHz to 930 MHz (and lower and higher) and in narrow and wide bandwidth. This chipset is new, and with the company's previous chipsets, is being used in various radio board products, including products of low volume.

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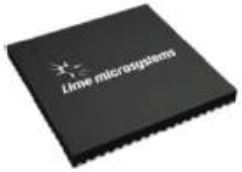
Lime microsystems
www.limemicro.com



LMS7002M

FPRF MIMO Transceiver IC
With Integrated Microcontroller

SUMMARY FEATURES

- Field Programmable Radio Frequency (FPRF) chip
- Dual transceiver ideal for MIMO
- User programmable on the fly
- Continuous coverage of the 100 kHz - 3.8 GHz RF frequency range
- Digital interface to baseband with on chip integrated 12 bit D/A and A/D converters
- Programmable RF modulation bandwidth up to 160 MHz using analog interface
- Programmable RF modulation bandwidth up to 60 MHz using digital interface
- Supports both TDD and full duplex FDD
- LimeLight ™ digital IQ interface – JEDEC JESD207 TDD and FDD compliant
- Transceiver Signal Processor block employs advanced techniques for enhanced performance
- Single chip supports 2x2 MIMO. Multiple chips can be used to implement higher order MIMO
- On-chip RF calibration circuitry
- Fully differential baseband signals, analog IQ
- Few external components
- Low voltage operation, 1.25, 1.4 and 1.8V. Integrated LDOs to run on a single 1.8V supply voltage
- On chip integrated microcontroller for simplified calibration, tuning and control
- Integrated clock PLL for flexible clock generation and distribution
- User definable analog and digital filters for customised filtering
- RF and base band Received Signal Strength Indicator (RSSI)
- 261 pin aQFN 11.5x11.5 mm package
- Power down option
- Serial port interface
- Low power consumption, typical 880mW in full 2x2 MIMO mode (550mW in SISO mode) using external LDOs
- Multiple bypass modes for greater flexibility

APPLICATIONS

- Broad band wireless communications
- GSM, CDMA2000, TD-SCDMA, WCDMA/HSPA, LTE
- IEEE® xxx.xxx radios
- WiFi operating in the Whitespace frequencies
- Software Defined Radio (SDR)
- Cognitive Radio
- Unmanned Aerial Vehicle (UAV)
- Other Whitespace applications

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Miniature Radar for Mobile Devices

Sharma, Praveen; Ouedraogo, Raoul; Perry, Bradley; Aubin, David; Levy, Todd; Souza, Daniel; Kitchens, Jonathan; Peabody, John
MIT Lincoln Laboratory, Lexington, MA 02420

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Radio Astronomy and Earth Atmosphere (radar) base station arrays and computing,

and related

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To appear in 2013 IEEE International Symposium on Phased Array Systems & Technology. c 2013 IEEE

Design and Commissioning of the LWA1 Radio Telescope

S.W. Ellingson, J. Craig, J. Dowell, G.B. Taylor, J.F. Helmboldt

Abstract—LWA1 is a new large radio telescope array operating in the frequency range 10–88 MHz, located in central New Mexico. The telescope consists of about 260 pairs of dipole-type antennas whose outputs are individually digitized and formed into beams. Simultaneously, signals from all dipoles can be recorded using one of the telescope's "all dipoles" modes, facilitating all-sky imaging. Notable features of the instrument include four independently-steerable beams utilizing digital true time delay beamforming, high intrinsic sensitivity (≈ 6 kJy zenith system equivalent flux density), large instantaneous bandwidth (up to 78 MHz), and large field of view (about 3–10◦, depending on frequency and zenith angle of pointing)….

LWA1. NASA photo.

Non-astronomical applications of the LWA1 include study of the Earth's ionosphere, meteor ionization trails, and propagation by reflection from aircraft. A vivid example is shown in Fig. 16. Recent results on ionospheric characterization and meteor trails are documented in [15] and [16], respectively….

[15] J.F. Helmboldt et al., "Passive over-the-horizon radar with WWV and the first station of the Long Wavelength Array," Radio Sci., submitted, 2013. Preprint: http://www.ece.vt.edu/swe/lwa/memo/lwa0195.pdf.

[16] J.F. Helmboldt et al., "at 55.25 MHz with the first station of the Long Wavelength Array," Radio Sci., submitted, 2013.

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BRAMS Listen to the meteors
Belgian Institute for Space Aeronomy

BRAMS (Belgian RAdio Meteor Stations) is a network of radio receiving stations using forward scattering techniques to study …meteoroid population…. coordinated by the Belgian Institute for Space Aeronomy (BISA)…. A very fruitful collaboration between professionals and amateurs since most stations are hosted either by Belgian radioamateurs, groups of amateur astronomers or astronomical public observatories. A dedicated beacon was installed in … 2010 in Dourbes (South of Belgium) … and acts as the transmitter.

The beacon

8m x 8m metallic grid is used as reflector…. the power is mainly emitted upward and the gain is increased by 3.6 dB compared to the [older crossed yagi upright] Ieper beacon.

Frequency	49.970 MHz
Power	150 W
Polarization	RHCP
Waveform	cw

Proceedings of the IMC, Sibiu, 2011

BRAMS : status of the network and preliminary results

Recently, the Belgian Institute for Space Aeronomy has been developing a Belgian network for observing radio meteors using a forward scattering technique. This network is called BRAMS (Belgian RAdio Meteor Stations). A radio transmitter [beacon] emits a circularly polarized pure sine wave toward the zenith at the frequency of 49.97 MHz. The receiving network consists of about 20 stations....This will enable a detailed analysis of the meteor...physical parameters of the meteoroids can be obtained. An interferometer....

The Earth's atmosphere is constantly hit by thousands of meteoroids.... 40 to 100 tons per day. They play a crucial role in a number of astronomical and aeronomical studies and,... pose a significant threat to space craft.... Here, we propose to study the meteoroid population with...forward scattering techniques and a dedicated beacon as transmitter.... the advantages of a forward scattering system over traditional radar systems will be briey discussed.

This is far simpler, relatively inexpensive meteor-trail-study network outlying stations compared with the much larger, major ones also described in these slides that also use radio frequencies in low VHF (~25- 55 MHz +/-) for studying earth atmosphere (with radar techniques: transmit and receive) and radio astronomy (receive only).

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References 2: Re advanced base stations - adapting phased arrays used in space and earth atmosphere radio receive and radar systems.

KAIRA: The Kilpisjärvi Atmospheric Imaging Receiver Array—System Overview and First Results

IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 53, NO. 3, MARCH 2015Derek McKay-Bukowski, Juha Vierinen, Ilkka I. Virtanen, Richard Fallows, Markku Postila, Thomas Ulich, Olaf Wucknitz, Michiel Brentjens, Nico Ebbendorf, Carl-Fredrik Enell, Marchel Gerbers, Teun Grit, Peter Gruppen, Antti Kero, Toivo Iinatti, Markku Lehtinen, Henri Meulman, Menno Norden, Mikko Orispää, Tero Raita, Jan Pieter de Reijer, Lassi Roininen, Arno Schoenmakers, Klaas Stuurwold, and Esa Turunen

THE European Incoherent Scatter (EISCAT) radar facility in northern Fenno-Scandinavia [1] is planned to undergo a major upgrade. Termed "EISCAT_3D," this upgrade project is nearing the end of its preparatory phase and will use modern phased-array technology in place of the radio dishes, which have been used successfully with the current EISCAT system for more than 30 years [2].

The KAIRA station comprises two arrays of 48 dual-polarization antennas; the low-band antenna (LBA) array covers a nominal frequency range of 10–80 MHz and the high-band antenna (HBA) array covers a nominal 110–270 MHz. The intervening gap is the broadcast allocation of FM radio, which is deliberately excluded. Recent advances in digital signal processing and computing are utilized, resulting in the rapid control of these antennas using digital multibeamforming techniques.

The antenna and signal processing system chosen for KAIRA is the same as that used in the Low-Frequency Array (LOFAR) International Telescope, a radio telescope network intended for low-frequency astronomy, designed and produced by the Netherlands Institute for Radio Astronomy (ASTRON) and Dutch industry [3]. This choice was motivated by the fact that the development work on LOFAR had already been completed, that the system was already tested, that a large international user community existed for support and that it gave an opportunity to evaluate a general-purpose radio astronomy design for use with atmospheric/ionospheric applications. The LOFAR system is a phased array with no moving parts, which is beneficial in an Arctic environment. Additionally, LOFAR has been designed for mass-production of low-cost components that are moderately quick to deploy and commission. The system permits rapid pointing with multiple beam formation and has high sensitivity. Furthermore, the broad-band nature of this system also ensures that many different transmitters can be received with the hardware.

What KAIRA sets out to achieve is the application of radio astronomy technology to geoscience applications such as riometry, incoherent scatter radar and ionospheric scintillation

Comments. In below pages, we explain the relevance of KAIRA to our planned master stations to use ~200 MHz 200 MHz high-band VHF spectrum and 'Paging' Part-22 low-band VHF spectrum in the '40' MHz range (35/43 MHz, potentially expanded if federal agencies allow use of their adjacent spectrum for our planned nonprofit government-support applications).

These planned master stations will use said high and low VHF ranges in (1) Meteor Burst (MB) signaling mode (using plasma trails created by incoming meteoroids, in which the low VHF is most effective, and (2) for radio multilateration positioning (along with N-RTK positioning) of drones, aircraft, and other things in the atmosphere, and associated communications, including to support Nationwide Drone Wireless (NDW), *in which the high VHF is best.*

As the EISCAT 3D systems shows (see below), the lower 900 MHz is also effective and adds capabilities. We plan to use mLMS, nLMS, MAS and Part 22 spectrum we hold for these capability.

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KAIRA: The Kilpisjärvi Atmospheric Imaging Receiver Array—System Overview and First Results

IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 53, NO. 3, MARCH 2015

Derek McKay-Bukowski, Juha Vierinen, Ilkka I. Virtanen, Richard Fallows, Markku Postila, Thomas Ulich, Olaf Wucknitz, Michiel Brentjens, Nico Ebbendorf, Carl-Fredrik Enell, Marchel Gerbers, Teun Grit, Peter Gruppen, Antti Kero, Toivo Iinatti, Markku Lehtinen, Henri Meulman, Menno Norden, Mikko Orispää, Tero Raita, Jan Pieter de Reijer, Lassi Roininen, Arno Schoenmakers, Klaas Stuurwold, and Esa Turunen

Notes.

Below and following pages are excerpts from this article. Comments are shown in shaded text boxes. Certain underlining is added. The full article is attached as a separate exhibit.

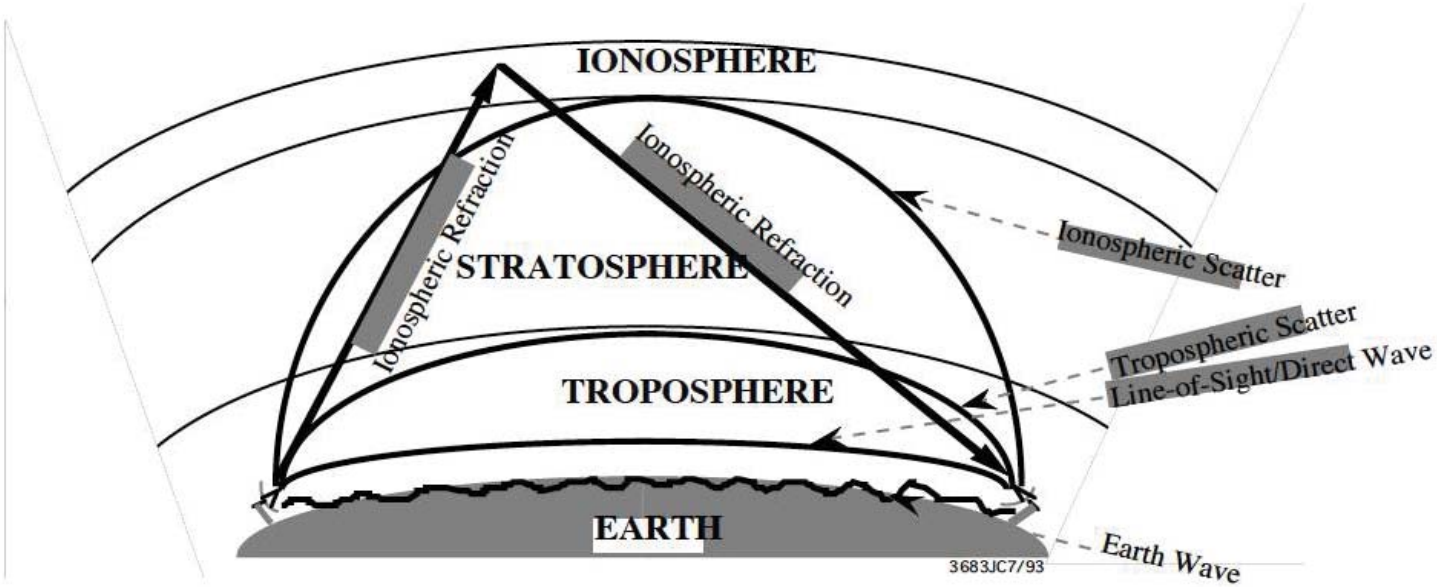

Figure 1-1. Electromagnetic Propagation

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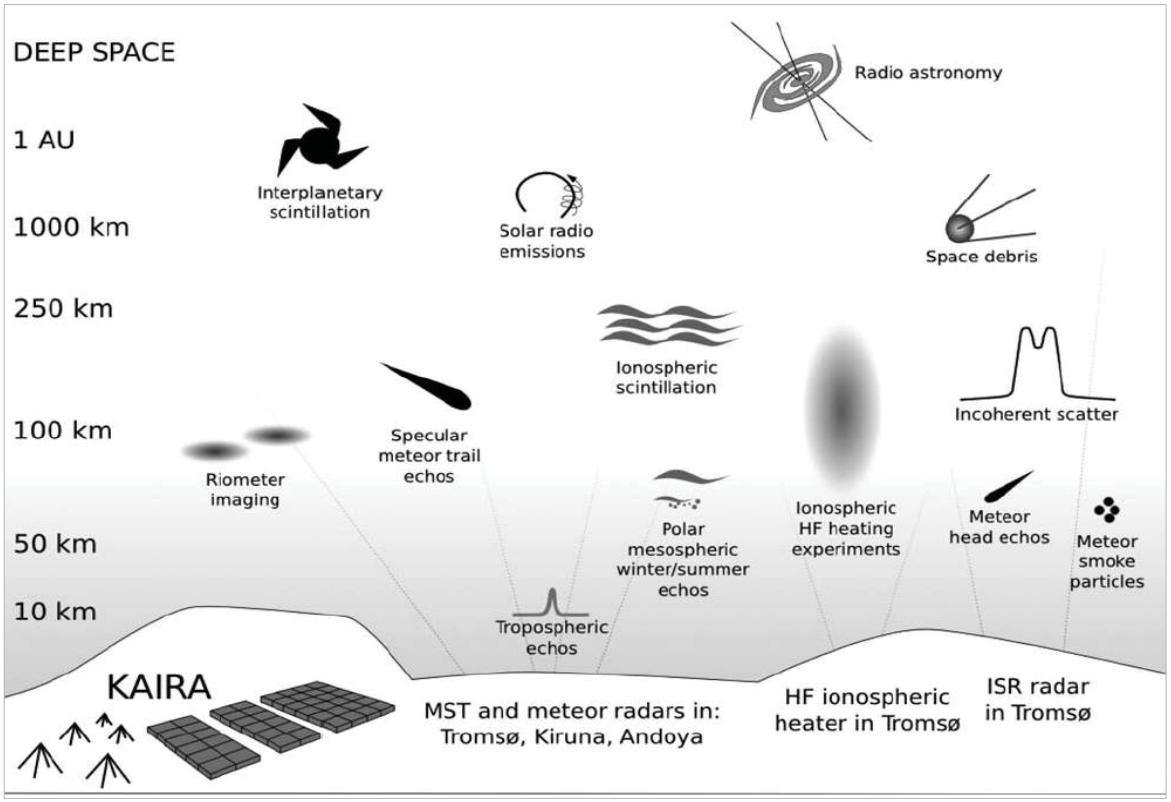
The KAIRA station comprises two arrays of 48 dual-polarization antennas; the low-band antenna (LBA) array covers a nominal frequency range of 10–80 MHz and the high-band antenna (HBA) array covers a nominal 110–270 MHz. The intervening gap is the broadcast allocation of FM radio, which is deliberately excluded. Recent advances in digital signal processing and computing are utilized, resulting in the rapid control of these antennas using digital multibeamforming techniques.

Comment.

In below pages, we discuss some of the capabilities depicted below left, and how we can achieve some of them– and by simple adaptations— also provide meteor burst (MB) signaling (using "specular meteor trails" and "meteor heads" depicted below) and Multilateration and associated communications, including for Nationwide Drone Wireless, using ~200 MHz 200 MHz, '40' MHz, and lower 900 MHz licenses we hold.



Comment.

Also note the "Ionospheric HF heating experiments" observation function depicted at left. High Frequency (HF) heating, along with other "geo engineering" methods being studied (and some say, already being implemented, e.g. "chem trails") are important areas of science and technology, since they may be needed to mitigate global warming and other environment degradation, as discussed in the relevant literature.

Thus, our planned use of these stations, using adaptations of KAIRA/ EISCAT/ LOFAR have high importance for environment science, prediction and protection.

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Comments. The radio antenna phased arrange is composed of simple, robust, modular elements. It is the computing software and hardware that turns these into a powerful, adaptive radio instrument. The size of the phased antenna array station (a location or facility) can easily be varied in accord with the purpose of each station to be used. The low VHF band antenna or (LBA) uses exposed antenna elements (left) and the high VHF band antenna (HBA) uses "tiles" on a frameset– see below (framesets above ground are not needed in less severe environments, as in most LOFAR stations, as as in most all of the continental US).

Fig. 4. LBA array with aerial #35 in the foreground. The black "cap" at the top of the post contains two low-noise amplifiers (one per polarization).

Fig. 2. Newly completed KAIRA site. August 2012.

In addition to the KAIRA instrument, the site has a simple office, storage, mobile network connectivity and power….. The site is close to many other scientific facilities as well as local infrastructure, access roads, and communication.

Fig. 3. HBA tile antennas (#83 and #96) on the timber framesets. The material at the base of the frameset is a strip of geotextile, used to prevent erosion along the array edges and between the tiles.

Comment. See left: The site is generally radio-frequency quiet but also close to facilities as noted, and many facilities and road vehicles create some RF noise. The instrument has means to mitigate ambient RF noise, as well as galactic RF noise.

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A. *Bistatic Incoherent Scatter Radar*

Multistatic incoherent scatter radar measurement capability offers the possibility of instantaneously measuring a full profile of vector velocities, which can be used, e.g., to derive ionospheric neutral winds and electric fields [30]–[32].

To demonstrate that KAIRA can contribute to multistatic incoherent scatter radar measurements, we performed a bistatic radar experiment on August 21, 2012 together with the EISCAT VHF radar in Ramfjordmoen, approximately 85 km northwest from KAIRA. In this experiment, we transmitted an optimized code group [33] of 20 codes with 128 μs Bd lengths and 10 bits per code. Fig. 16 shows the lag-profile inversion [34] result of a 512-s integration period.

During the experiment, we had 30 dual-polarized beams intersecting the Tromsø VHF vertical beam at altitudes between 90 km and 2000 km. In this plot, we have combined all

Comment.

Multistatic (using many locations) radar, involving radio *transmission and reception*, is a capability KAIRA and similar phased-array highly-synchronized stations in network(s).

As noted in Fig. 16, lower 200 MHz is part of the radio range used (this is elsewhere apparent in this article on KAIRA which uses both low and high band VHF into the lower 200 MHz (including all of the ~200 MHz spectrum range).

The same networked station can perform multilateration location of things in the atmosphere and space—including drones and aircraft— either using transmissions from the earth stations, or from the remote things above, or a combination.

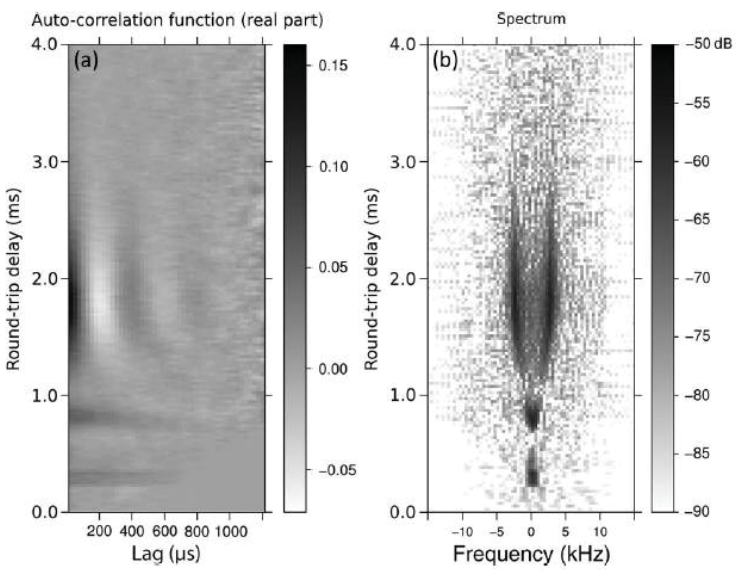

Fig. 16. First multibeam bistatic incoherent scatter radar measurement demonstrating the measurement of the incoherent scatter auto-correlation function (a), and the derived full ionospheric incoherent scatter spectrum profile (b) with respect to the transmitter frequency (224 MHz). The vertical axis is the total round-trip delay of the signal from transmission to reception.

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KAIRA is ideally suited to riometry observations because of its location, multibeam capability, all-sky imaging and multifrequency signal processing over a wide part of the VHF spectrum. Due to the high-latitude location of KAIRA, it will measure frequently occurring D-region electron density enhancements due to high-energy particle precipitation inside the auroral oval and inside the outer radiation belt.

The multibeam capability of KAIRA allows spatially-resolved riometer measurements by using beams with narrow fields-of-view, much in the same way that other imaging riometers [37] function. However, the wide-band nature of KAIRA will allow measurements to be done simultaneously in the frequency range of 10–80 MHz, allowing us to measure the frequency dependence of the absorption, in addition to adding significantly more statistics. To the best of our knowledge, KAIRA is the first wide-band imaging riometer built.

It has been shown by multiple authors [38], [39] that a measurement of frequency dependent riometer absorption can be used to estimate the electron density height profile. This has so far only been done using riometers operating at a few discrete frequencies. KAIRA will be able to perform frequency continuum measurements between 10 and 80 MHz.

C. *Ionospheric Scintillation*

Ionospheric scintillation is the scintillation of the radio signal from a compact source due to scattering and refraction from density variations in the ionosphere. The study of this phenomenon is most often carried out using satellite measurements from GPS and other beacon satellites orbiting the Earth. Such measurements can be used to determine information on the density irregularities giving rise to the scintillation and the effects of these on the radio signal itself [41], information on increasing importance given the modern reliance on satellite communications.

Comment. The capabilities described at the left can be used in Meteor Burst (MB) radio signal transmissions for communications, time transfer, positioning, encryption, etc. The MB ideal frequency range from about 30-50 MHz is much smaller is less than two times the lower frequency, compared to eight time the 10-80 MHz range described at the left. MB signaling also involves, for best functioning, both wide survey of the sky ("all sky" as described at left) to find the MB plasma trails, but also high-gain directionality ("narrow fields-of-view" as described at left) to maximize performance for use of each plasma trail in the wide field of view. Whereas techniques to achieve these two functions have been used in the past in "1G" (or first generation MB communications) with narrow band channels and radio equipment, and simpler antenna systems, the capabilities of current generation radio astronomy and earth-atmosphere radio-receive observation instruments (that can also be used for radio transmission, as we show in this PPT) are far greater, probably by some order(s) of magnitude, as modern computing hardware and software (on which they are built) are that much greater then those of decades past.

Comment. GPS-GNSS signals suffer from scintillation. The MB adaptations of these radio astronomy and earth atmosphere observation instruments can be used to improve real-time determinations, and thus projections, of scintillation which can improve GPS-GNSS corrections and thus performance. In similar fashion, reported in various studies, MB signaling systems can be used to improve near term weather predictions, and longer term global climate change prediction.

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Because of ever-present RFI, parts of the measurement, particularly below 30 MHz, are corrupted with signals of non-cosmic nature. To remove these, we make the assumption that the variability of the sky-signal with frequency at each instant of time is smooth. We can then use an iterative least-squares fitting procedure to then remove this interference. During each step of the iteration, we fit a third-order polynomial to the power spectrum. Then, outliers are identified. If there is a frequency bin with power that deviates more than 2.5-σ from the least squares polynomial fit, it is tagged as an outlier and removed. Once the iteration is finished, the outliers are discarded from the measurement. In the absence of a way to estimate measurement errors, we estimate a sample variance from the outlier-removed polynomial linear least-squares fit residuals. We used visual inspection of the results to determine that the automatic scheme works to a reasonable degree of accuracy. Also, the best fit for absorption, shown in Fig. 17(b), does not show significant contribution due to RFI, indicating that RFI is properly removed from the measurements.

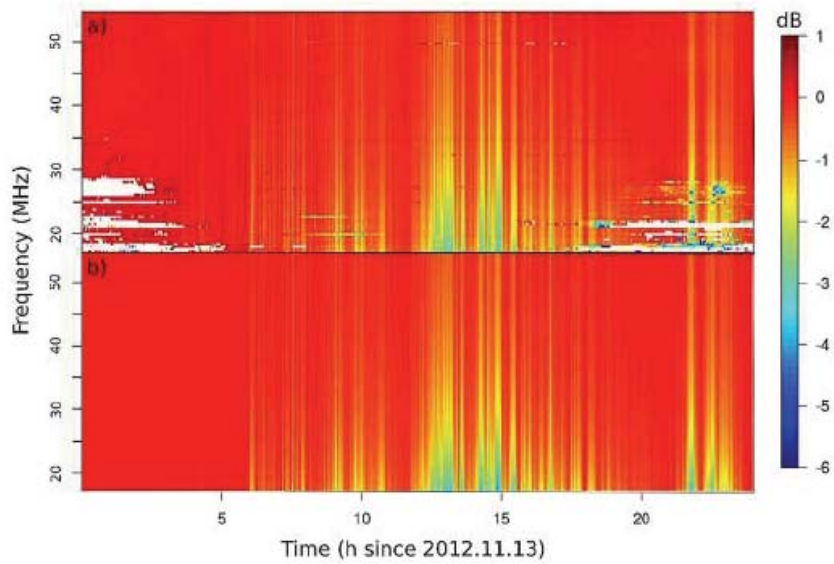

Fig. 17. Measured absorption on the vertical beam of the LBA, starting from 12 UTC on 13 November 2012. The measured absorption is shown above (a), and the forward model, corresponding to the maximum likelihood estimate of an electron density profile is shown below (b).

Comments. In 30-50 MHz, and especially at ranges below 30 MHz, radio frequency interference (RFI) can be substantial. This shows a means to remove this RFI using the power of the sophisticated array instrument. FRI removal is important to enhancements in Meteor Burst signal transmissions for communications, timing, radar, and encryption, as is well known in the relevant literature.
Also, since major radio astronomy/ earth atmosphere phased array observation (and bistatic and multistatic radar) instruments of these sorts have increasing use and evolution, this RFI removal and other functions are likely to increase in time, and more so than can be increased in smaller and more simple radio/antenna/computer devices.

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D. VLBI

Because the KAIRA station is not directly connected to the LOFAR network, it currently cannot participate in standard international LOFAR observations. For certain special projects requiring the highest possible resolution, KAIRA can nevertheless be an important contribution to VLBI with LOFAR and other stations worldwide. The baseline to LOFAR station FR606 (Nançay, France) of 2600 km is twice as long as the longest within LOFAR between stations FR606 and SE607 (Onsala, Sweden).

In March 2013, KAIRA participated in an intercontinental experiment with two LOFAR stations, i.e., SE607 and DE601 (Effelsberg, Germany), and the LWA at about 8000 km distance. The comparatively low sensitivity of these low-band observations and a number of minor technical problems make the analysis difficult, and fringes have not been found yet.

A technical test was performed on May 13, 2013, in which KAIRA and the DE601 LOFAR station (2185-km baseline) observed the bright pulsar B0809+74 in the high band in short blocks of a few minutes each. The following results are based on only 95 s of data between 15:00:08 and 15:01:43 UTC. 48 MHz of bandwidth centered on 143.26 MHz were recorded at both stations. This is the longest baseline result so far achieved between LOFAR-built systems, significantly exceeding the longest current baseline of the International LOFAR Telescope (only 1302 km).

Comment. The left describes how this one KAIRA 10-80 / 110-270 MHz radio astronomy and earth atmosphere (and sky radar transceiver) system *can also* be used as a station in the LOFAR Very Long Baseline, LOFAR Very Long Baseline Interferometry (VLBI) network instrument that uses many locations in Western Europe and Scandinavia.

The largest or "master" stations we contemplate using in the US could do the same, and use time sharing or geographic extensions to satellite stations, to eliminate radio interference from the stations when used to transmit (the VLBI radio/ sky observation functions are radio-receive only and, for the frequencies being observed, must be in radio-quite areas and times).

For example, see in this PPT description of EISCAT, whose scientists seek similar stations in the US to coordinate with. Worldwide coordinated VLBI is desirable, ultimately, and to some degree is already being performed by certain linking of instruments. The more stations are linked, the better the resolution and greater the intensity / reception ability. This has important implications from basic science to increased prediction of planetary environment health, needed to better decide on measures to mitigate destructive industries and behaviors that threaten quality and sustainability of civilization and life.

KAIRA - page 8. End.

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References 2: Re advanced base stations - adapting phased arrays used in space and earth atmosphere radio receive and radar systems.

Rutherford Appleton Laboratory
Space Science & Technology

LOFAR

Derek McKay-Bukowski

d.j.mckay@rl.ac.uk
Space Science & Technology Department
Chilbolton Observatory, Hampshire
UNITED KINGDOM

With thanks to...
Bruce Swinyard (RAL),
Harry Smith (Oxford)
Steve Rawlings (Oxford),
Rob Fender, (Southampton)

Presented at the EISCAT User Workshop, 20-May-2010, Uppsala, Sweden.

Notes.

Below pages are a few of the slides excerpts from this PPT. Comments are shown in shaded text boxes. Certain underlining is added.

The full PPT is attached as a separate exhibit.

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LOFAR

Core stations in the Netherlands

Dense core:
- *10km*
- *18 stations*

Medium baselines:
- *100km*
- *18 further stations*

LOFAR frequency coverage
- HB = 120–240 MHz
- LBH = 30–80 MHz
- LBL = 10–30 MHz (possible, but not planned at this stage)

Antenna arrays of either angled dipoles or tiles (with embedded bowtie antennas)

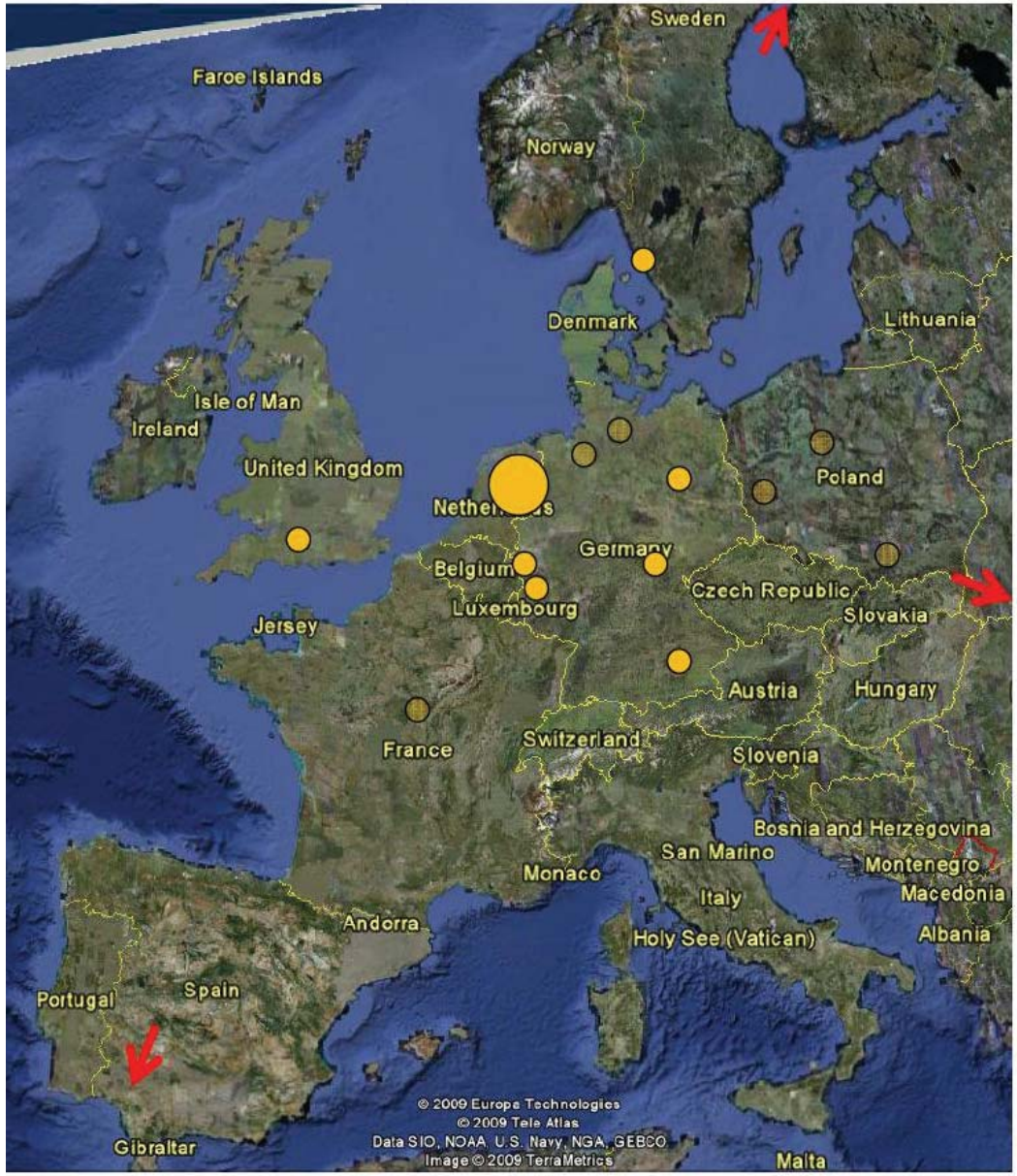
More on this later...

Covers most of the VHF band....

Although *VHF*, it is still *low* frequency by radio astronomy standards

8 independent 4 MHz beams

12-bit digital output at 200 MS/s



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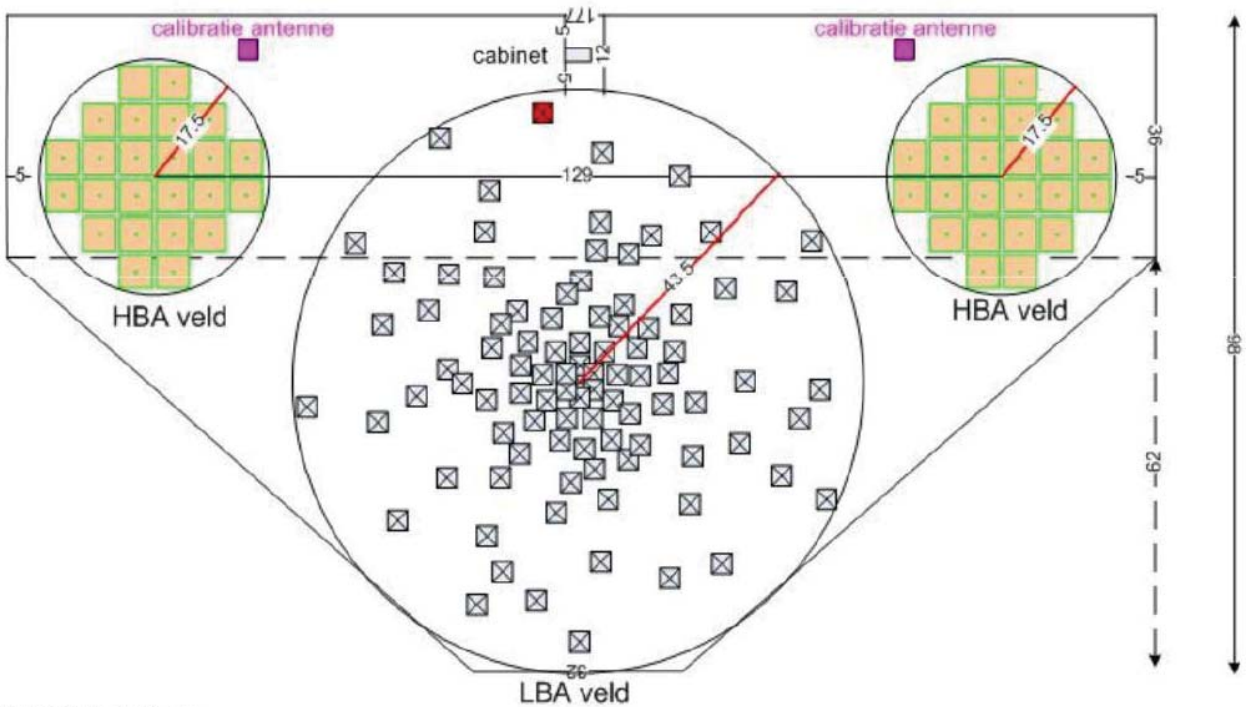
Dutch core station
(Remote station with combined HBAs)



LOFAR CORE station:
=> LBA veld heeft diameter van 87 meter en bevat 96 antennes
=> 2 HBA velden (elk met een diameter van 35 meter) bevatten elk 24 antennes

Arie Huijgen, 23 mei 2008 vs 1.0

Costs:

Basic hardware £1.3M [and]

Staff effort

Land

Plant & equipment hire

Ground works

Comments. HBAs are the High VHF Band Antenna arrays, that include the lower 200 MHz range, including all of ~200 MHz range. LBA is the Low VHF Band Antenna array from 10-110 MHz, including the '40' MHz range we have in our Part 22 'Paging' licenses. The dimensions are shown above. A station need not be this large, or may be larger, depending on its purposes. "Basic hardware" costs indicated above should come down with volume, as with some of the other costs as well. This is very low cost for the performance and upgradability. Also, some such "master" stations (in our planned systems) need not be this large for our purposes which will also lower costs.

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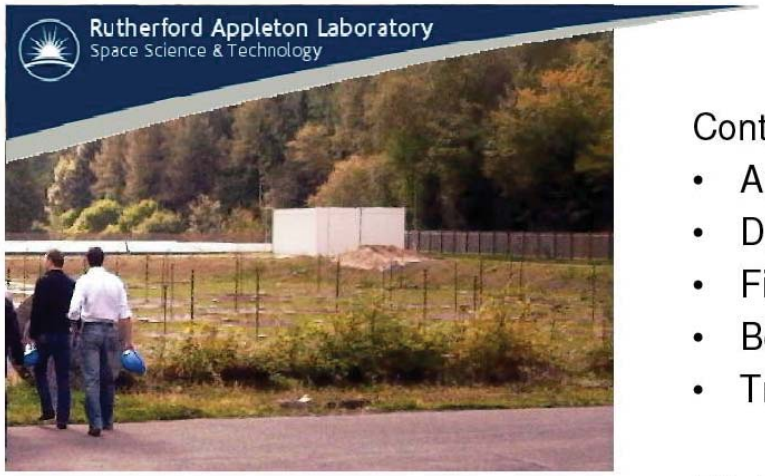
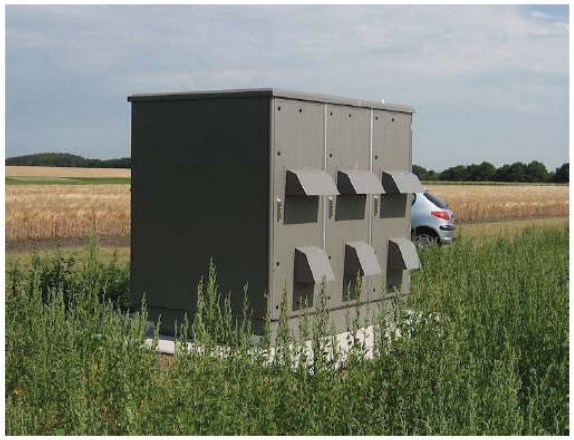


RF Cabinet

Contains:

- Amplifiers
- Digital receivers
- Filter banks
- Beam-formers
- Transient buffers

Effelsberg: double-shipping crate
Exloo: external rack storage unit
Chilbolton: single



The LOFAR design is modular...
Flat packed telescope, just provide your own:
Philips Screwdriver, Allen key, etc. (just the few localisations)
Assistance provided by manufacturers and ASTRON
Examples shown (mostly from the Chilbolton station)

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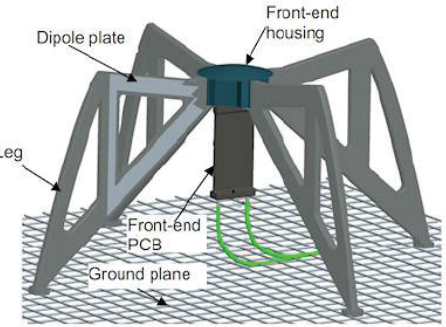
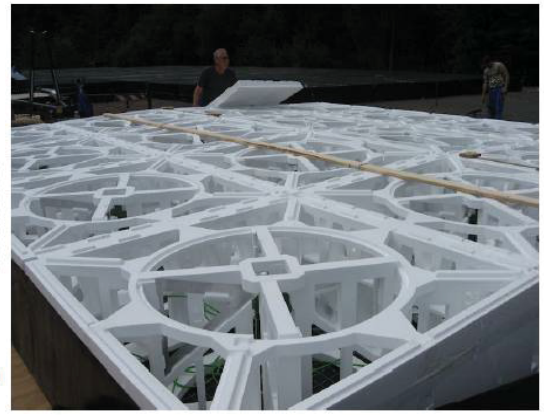
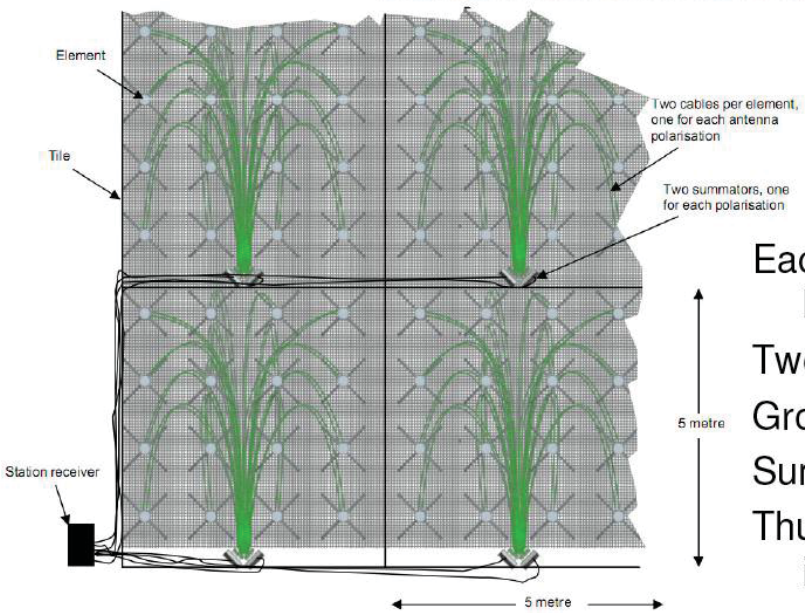
HBA Tile Construction

Bowtie "spiders





Path-preserving cabling



Each tile has 4 × 4 crossed bowties

Two linear polarisations

Ground plane = 5 × 5cm gridsize

Summators add at a tile-level

Thus a tile is the smallest interferometric element

Comments. HBAs are the High VHF Band Antenna arrays, that include the lower 200 MHz range, including all of ~200 MHz range. Many "tiles" make up a phased array.

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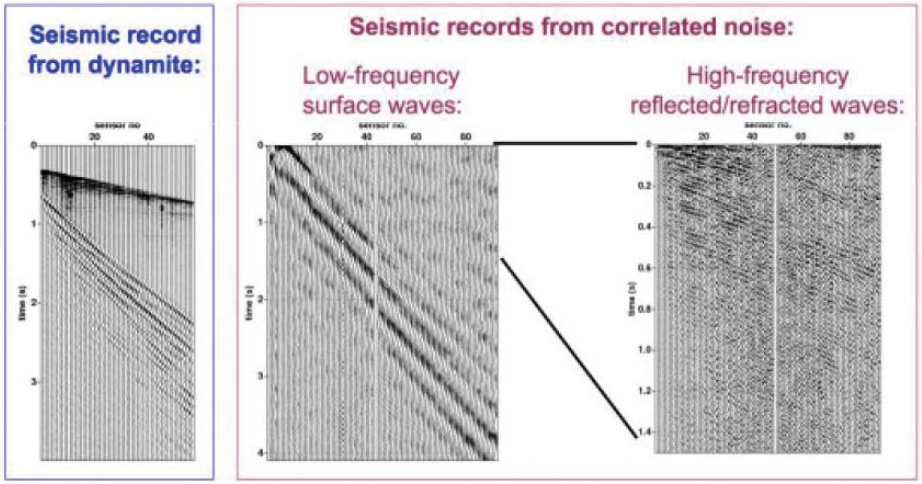
Central Processing

IBM, Blue-Gene/P supercomputer

- 2 x B-G/P racks
- 8k cores
- 27.4 Tflops
- 800 Gbit/s I/O
- Correlator software

Blue Gene/P, tiered architecture



LOFAR has additional non-astronomy applications, such as geo-seismology and precision agriculture.

Comments. Re top: Supercomputing cost are decreasing and in any case, are essential to advanced radio systems of the sort we plan (and provide other functions once available). Re Bottom: Seismic monitoring and alerts are major programs in California, Nevada, Oregon and Washington States: See the discussion in the Applications on "Environment Wireless."

LOFAR – page 6. End.

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References 2: Re advanced base stations - adapting phased arrays used in space and earth atmosphere radio receive and radar systems.

http://www.eiscat.com/about/whatiseiscat_new

What is EISCAT

EISCAT, the *E*uropean *I*ncoherent *Scat*ter Scientific Association, is established to conduct research on the lower, middle and upper atmosphere and ionosphere using the incoherent scatter radar technique. This technique is the most powerful ground-based tool for these research applications. EISCAT is also being used as a coherent scatter radar for studying instabilities in the ionosphere, as well as for investigating the structure and dynamics of the middle atmosphere and as a diagnostic instrument in ionospheric modification experiments with the Heating facility.

There are ten incoherent scatter radars in the world, and EISCAT operates three of the highest-standard facilities. The experimental sites of EISCAT are located in the Scandinavian sector, north of the Arctic Circle. They consist of two independent radar systems on the mainland, together with a further radar constructed on the island of Spitzbergen in the Svalbard archipelago - the EISCAT Svalbard Radar – Scandinavia.

The EISCAT UHF radar operates in the 931 MHz band with a peak transmitter power of more than 2.0 MW and 32 m, fully steerable parabolic dish antennas. The transmitter and one receiver are in Tromsø (Norway). Receiving sites are also located near Kiruna (Sweden) and Sodankylä (Finland), allowing continuous tri-static measurements to be made.

The monostatic VHF radar in Tromsø operates in the 224 MHz band with a peak transmitter power of 2 x 1.5 MW and a 120 m x 40 m parabolic cylinder antenna, which is subdivided into four sectors. It can be steered mechanically in the meridional plane from vertical to 60° north of the zenith; limited east-west steering is also possible using alternative phasing cables.

Comment: EISCAT is discussed in above slides. Blue text color is added. As noted, these use lower 200 MHz and 900 MHz. Following is from another EISCAT article.

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The full article is attached as a separate exhibit and is available here: https://eiscat3d.se/sites/default/files/publications/p29-31_EISCAT-3D_H_Res.pdf

Constructing an atmosphere watchdog

EISCAT_3D, a next-generation phased array technology radar, marks a major advance for environmental scientists by establishing five new radar sites which could transform the way we measure changes in the Earth's atmosphere.

Next-generation technology

EISCAT_3D is an improvement on traditional incoherent scatter radars (ISR) which were unable to be operated as continuously measuring geophysical instruments… the new continuous operation capability with distributed solid-state power amplifiers is a major change in the … the ISR method".

The new radar system will house several large fields of antennas, known as phased arrays, some of which will be equipped to both **transmit** and receive signals, whilst others will remain passive receivers….

Furthermore, the new model will be a 'software radar' meaning, unlike its predecessor, EISCAT_3D can easily be improved and updated simply by changing the software and necessary parts of the hardware as new technologies and solutions arise.

The sites will be spread across the northern regions of Norway, Sweden and Finland,…

Phases to completion

…planned to finish in 2016 ….continuously and largely autonomously… 30 year lifespan.

International collaboration ….

EISCAT_3D follow in this tradition of global

collaboration, as is evident by their strong ties with the U.S. "In the future, we would like to regard our radars, and also any other new generation incoherent scatter radars, as a joint global instrument, ….

…. organising global incoherent scatter radar schools along with colleagues from the U.S…. discussions by the EU and the National Science Foundation. …

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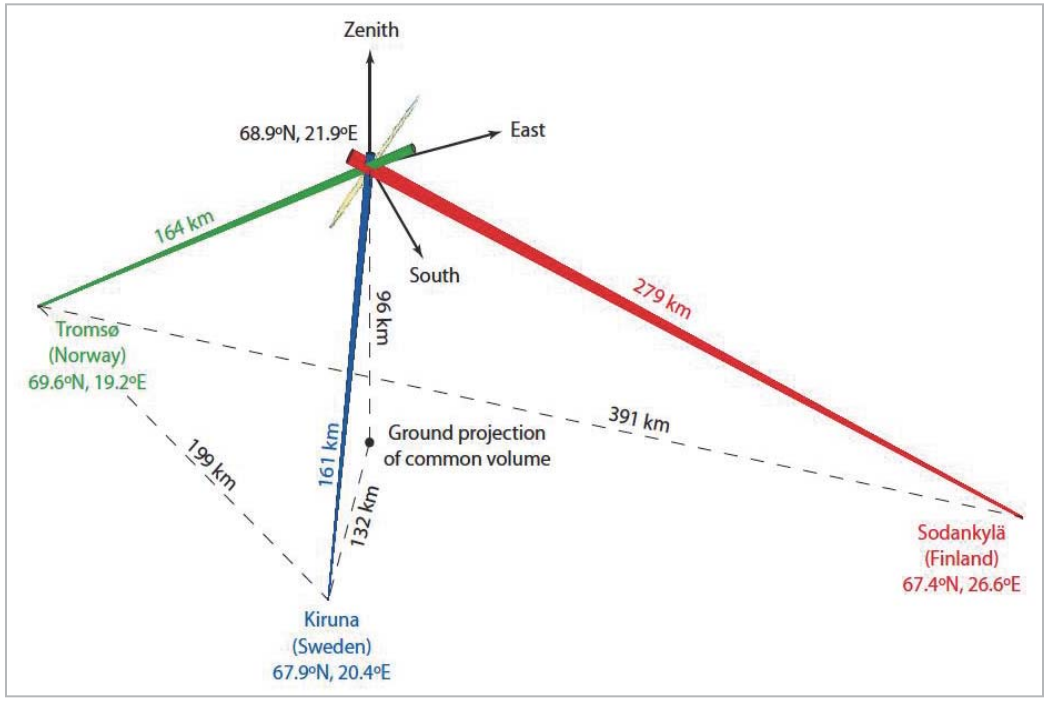
significant contributions to understanding the impact climate change has on the upper layers of the atmosphere by measuring any changes.

The radar will also be able to aid satellite observations of the ice and snow in polar areas, which are also feeling the effects of changing climate conditions.

An emerging type of environmental problem which EISCAT_3D will be able to observe is space junk also known as space debris. The term refers to all of the manmade objects that are left in orbit around the Earth after they can no longer fulfill any purpose. Observing these objects allows ISR to play a role in risk management since they pose a threat to space missions and satellites which could enter their path. Since EISCAT_3D will be 10 times more sensitive than any radar currently available, the accuracy in detecting space junk will be greatly increased.

Another major benefit of this new model is that it will be designed to allow for upgrades: "It is important to note that since the EISCAT_3D facility will be constructed for an operational period of several decades, the software radar concept allows the upgrading and enhancement of the measurement capability according to new solutions in computing and data storage".



Comment. Above depicts functions of EISCAT. It is from the paper: "HIGH-RESOLUTION METEOR EXPLORATION WITH TRISTATIC RADAR METHODS," Johan Kero, IRF Scientific Report 293, Swedish Institute of Space Physics, Kiruna 2008

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References 2: Re advanced base stations - adapting phased arrays used in space and earth atmosphere radio receive and radar systems.

The Owens Valley Long Wavelength Array

* * * *

In order to study the process of galaxy formation it makes sense to look for the most distant galaxies possible. The further away a galaxy is, the further back in time we are seeing it. This is problematic because distant galaxies are typically found and studied with optical and near-infrared telescopes. At large distances, the bound-free opacity of neutral hydrogen shrouds these galaxies from view.

The LWA circumvents this problem by looking for highly redshifted 21 cm photons that are characteristic of neutral hydrogen. Instead of studying the proto-galaxies themselves, the LWA makes it possible to study the gas around these galaxies. How do galaxies form and develop into the wonderfully complex and beautiful systems we see today? How did they interact with the surrounding gas during this process? When did galaxy formation start and how long did it take? All of these questions are wide-open. However, with the LWA at Owen's Valley, we will begin to probe the answers to some of these questions.

The Transient Radio Sky

Time domain astronomy is a rich field with high potential for new discoveries, in all wavelength regimes. The success of transient searches in the optical (with the Palomar Transient Factory (PTF), the Catalina Real-time Transient Survey, the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS), etc.) and in the X-ray and gamma-ray skies (with the Swift Gamma-Ray Burst Mission and the Fermi Gamma-ray Space Telescope) highlights the vast scientific yield and exciting nature of time domain astronomy. The variable and transient radio sky, however, remains relatively poorly sampled, due to the limited fields of view, sensitivity, and survey speeds of traditional radio interferometers, despite the evidence that radio transient phase space is equally as rich as its counterparts in other wavelengths.

The Owens Valley LWA will open up the field of radio transients -- with full cross-correlation of all of its 33,000 baselines and instantaneous imaging by a dedicated transient backend, the LWA will produce all-sky images every second with approximately 1Ëš resolution in all 4 polarizations (IQUV), reaching less than 10 mJy RMS noise in a 1 hour integration. This all-sky sensitivity means we can perform targeted transient searches as well as conduct blind surveys to better sample the transient phase space and reveal new and exciting populations of radio transients.

The LWA transient search is particularly aimed at the detection of coherent radio emission from extrasolar planets, similar to the extremely bright electron cyclotron maser emission produced by magnetized planets in our own Solar System. The direct detection of extrasolar planets through their auroral radio emission would provide measurements of magnetic field strengths and rotation rate, as well as serving as an indirect probe of interior composition and dynamics.

http://www.tauceti.caltech.edu/lwa/science.html

http://herrero-radio-astronomy.blogspot.hk/2013/06/wonderful-progress-at-owens-valley-long.html

Antennas	256 crossed broadband dipoles
Geometry	200 m diameter core array with 5 outrigger antennas extending to 365 m baselines; antenna positions optimized to minimize sidelobes (with a minimum spacing of 5 m to limit mutual coupling)
Bandpass	28 MHz to 88 MHz (limited by FM radio)
Back End	512 input correlator (LEDA) performing full cross-correlation of all the input signals with a transient cluster imaging these visibilities on a 1 second timescale
Field of View	130 degrees at the -6 dB point
Resolution	~1 degree at 80 MHz to ~4 degrees at 20 MHz

Comments. Same relevance is above references to other phased arrays for space and earth atmosphere radio receive and radar systems.

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References 2: Re advanced base stations - adapting phased arrays used in space and earth atmosphere radio receive and radar systems.

Advanced Modular Incoherent Scatter Radar (AMISR)

SRI leads development of a modular, mobile radar facility used by research scientists and students from around the world.

Under a grant from the National Science Foundation, SRI leads a collaborative effort in developing AMISR, a modular, mobile radar facility used by research scientists and students from around the world. Information about how to request usage of the facilities appears below.

AMISR is the first system to provide scientists with the technology necessary to collect critical data and study global climate trends from year to year. Scientists can now investigate the energy and momentum transfer among all layers of the Earth's upper atmosphere, accessing critical data on the complex physical processes that comprise the sun, magnetosphere, and ionosphere.

Data collected from the high-latitude atmosphere and ionosphere provide an opportunity for early detection of climate-change phenomena. AMISR monitors space weather events, which can potentially damage and interrupt power grids and satellite and electronic communication.

The novel modular configuration of AMISR allows relative ease of relocation…. Remote operation and electronic beam steering allow researchers to operate and position the radar beam instantaneously to accurately measure rapidly changing space weather events.

AMISR consists of three separate radar faces, with each face comprised of 128 building block-like panels over a 30- by 30-meter, roughly square, surface. The first three faces in Poker Flat, Alaska (PFISR), and Resolute Bay, Nunavut, Canada (RISR-N and RISR-C), are in use for scientific investigations…. Since each face of AMISR functions independently, AMISR can be deployed in up to three separate locations at the same time.

AMISR is made up of 4,096 antennas, giving a combined power of up to two megawatts. By phasing the signal coming from the individual antennas, the radar beam can be steered almost instantaneously from one position in the sky to another. This unique feature of AMISR is especially important for studying rapidly moving features of the atmosphere.

[From: https://www.sri.com/work/projects/advanced-modular-incoherent-scatter-radar-amisr]

Comments. This is another phased array similar to those above, but this is more modular, easy to relocate, and has allows near instantaneous beam steering. Also note the importance to climate change detection, and space-weather detection important for electric grid and communication protection.

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Wuhan Atmosphere Radio Exploration (WARE) radar: System design and online winds measurements

Zhao Zhengyu, Zhou Chen, Qing Haiyin, Yang Guobin, Zhang Yuannong, Chen Gang, and Hu Yaogai

…The Wuhan MST radar operates at very high frequency (VHF) band (53.8 MHz) by observing the real-time characteristics of turbulence and the wind field vector in the height range of 3.5–90 km…. This…Doppler radar is China's first independent development of an MST radar focusing on atmospheric observation. …

Advanced radar technologies are used, including highly reliable all–solid-state transmitters, low-noise large dynamic range digital receivers, an active phased array, high-speed digital signal processing, and real-time graphic terminals.

Introduction. Since the first very high frequency (VHF) radar in Jicamarca successfully observed atmospheric winds and turbulence in the 1970s […], VHF radars have been established successively all over the world to facilitate and boost worldwide atmospheric research.

Such VHF radars have developed into the most significant facilities for atmospheric remote sensing that are capable of continuously operating under all weather conditions with fine spatial and temporal resolutions. Currently, a large number of VHF radars for atmospheric research are under operation, situated from the polar region to the equatorial region….

Among the atmospheric VHF radars, the mesospherestra-tosphere- troposphere (MST) radars….MU radars are one of the most influential MST radars and have provided numerous important results and findings to further our understanding of the atmosphere and ionosphere.

With fine temporal and height resolutions, MST radars around the world provide an outstanding opportunity to extensively and intensively investigate various atmospheric phenomena such as wind measurements […], tropopause detection […], gravity waves […], atmospheric aspect sensitivity […], and ionospheric irregularities […].

…Wuhan University started the construction of the Wuhan Atmosphere Radio Exploration (WARE) MST radar…in March 2011, we implemented the successful trial operation of the WARE radar, which is the first MST radar in the mainland of China.

The Wuhan MST radar is a 53.8 MHz pulse-modulated monostatic Doppler radar with an active phased array system, which has capabilities of radio distance measurement and Doppler velocity measurement.

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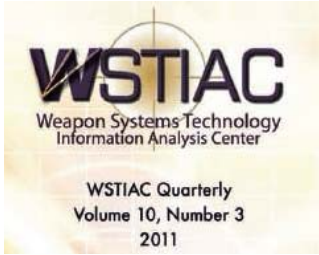
References 3. Multistatic radar for location. Same arrays as in References 2 can be used.

ANTENNAS AND RADAR SYSTEMS FOR INTEGRATING NAVIGATION AND COMMUNICATION CAPABILITIES WITH WEAPON PLATFORMS



ABSTRACT

This paper reviews the concept of a forward-scatter radar (FSR) which exploits the enhanced bistatic radar cross-section of a target in the forward direction (as opposed to the conventional back-scatter direction). FSR has the potential to reliably detect and track small air-vehicles with high sensitivity. Fundamentals of radar (including monostatic, bistatic, and multistatic) and a brief history are presented. Limitations of FSR radars are presented along with methods for overcoming them based on new technologies – accurate electromagnetic simulators, mesh networks, global positioning system (GPS) location of illuminators and receivers, and smaller and lighter transmitters and receivers. A program plan to accomplish these goals is given in the Appendices, along with an example of solving the target location for three transmitters and one receiver.

Comments. Materials and comments herein, including above, show how the new phased arrange antenna tech and systems, especially as we plan to adapt them, can be used for FSR and other forms of PNT (position, navigation, and timing). This article provides additional information on these topics.

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INTRODUCTION

In conventional radar configurations, the transmitter and receiver are collocated, and thus can be considered monostatic radar. Conversely, bistatic radar is composed of a transmitter and a receiver that are physically separated. Multistatic radar has transmitting and receiving apertures located in various positions. A recent paper makes it clear why a new look at multi-static systems is necessary at this time.

"Compared to conventional radars, multistatic radars have the potential to provide **significantly improved interference rejection**, tracking and discrimination performance in **severe EMI and clutter environments**. They can potentially provide significantly improved target tracking accuracy because of the large baseline between the various apertures. The resulting angular resolution can be orders of magnitude better than the resolution of a monolithic system (single large radar). The same angular resolution can provide improved interference rejection."[1]

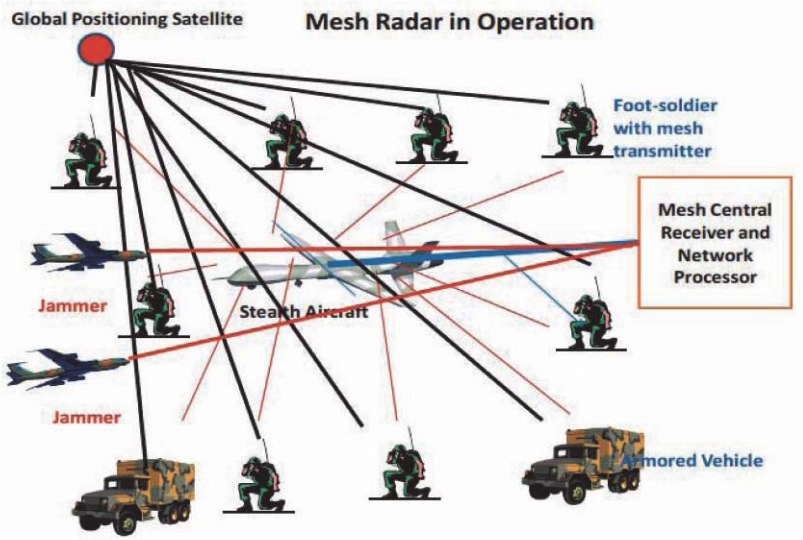

Figure 5. Illustration of mesh radar in operation.

In addition, orthogonal frequency division multiplexing (OFDM) can improve the performance of a radar network, in which each radar system would be either monostatic or bistatic. This configuration enables the classification of objects by ensuring each object is observed from different angles.[2]

Comments. Note the mesh net radio systems. For commercial and some other purposes, this can be via FCC-class "private commons" arrangements. Our companies are the first to apply for and have approved private commons classification. Also, the references indicated above [1] and [2] are in the full article included herewith as a separate exhibit.

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Reference 4.

Passive Radar and the Low Frequency Array

[We may include this article as a separate exhibit.]

Frank D. Lind[1], John D. Sahr[2]

[1] MIT Haystack Observatory, Route 40, Westford, MA 01886 USA
flind@haystack.mit.edu

[2] Department of Electrical Engineering, University of Washington, Box 352500, Seattle, WA 98152 USA
jdsahr@u.washington.edu

ABSTRACT

The proposed Low Frequency Array will be a powerful new radio telescope operating in the 15 to 240 MHz range. LOFAR will be a fully digital instrument with tens of thousands of antennas and receivers. In the currently proposed configuration LOFAR will also be capable of operating as a high performance passive radar system using FM radio stations as signals of opportunity. In this mode of operation LOFAR will observe geophysical targets such as ionospheric irregularities and meteor trails with high resolution in range, velocity, azimuth, and elevation. These phenomenon may be important to the operation of LOFAR as a radio telescope because of their potential to interfere with astronomical observations.

Comments. We researched this and other similar articles in recent years, some that we republished with comments, including the above (those that were permissible to do so), and used in past FCC filings. As with other references in this PPT including regarding KIARA, this article shows how LOFAR can be used for detection of meteor trail locations and movement through the atmosphere. This can be achieved using LOFAR-like arrays for Meteor Burst (MB) signaling for location and movement determination of man-made things in the atmosphere including drones, and things on moving on earth, when coupled with MB high accuracy timing and other now-cost-effective technologies, using low-band VHF in the 40 MHz range, and high VFH in lower 200 MHz including ~200 MHz. (Also, ~200 MHz-range spectrum was used, until recently, in the SPASUR radar system, reflecting the value of this spectrum range for detection of things in space. SPASAR is indicated in FCC ~200 MHz rules §80.385 (a)(2) note 2.

This can provide backup and an alternative to GPS-GNSS for PNT (position, navigation and timing) that is essential for national security and industries. (We may include this article as a separate exhibit.)

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Reference 5

PS86X1 is a PocketSpacecraft.com experiment to test systems and ideas for supporting the future interplanetary CubeSat and Thin-film Spacecraft/Lander/Rover (TF-SLR) mission communication and navigation needs of very large numbers (1000's) of very low mass (100mg – 5kg) spacecraft using phase array antennas and mechanically pointed commercial off the shelf (COTS) amateur radio equipment.

PocketSpacecraft.com

Date: 23rd October 2
Our ref: 7.1.7.3.19/PS
Page: 2 of 12

We would like to accomplish as much as the following as possible using both commercial off the shelf (COTS) amateur radio ground station equipment and the low frequency array for radio astronomy (LOFAR[2]):

1. Receive and decode the beacon
2. Determine the position of the beacon using time difference of arrival (TDOA) multilateration
3. Determine the position of the beacon using trilateration
4. Determine the position of the beacon using triangulation or other relevant system specific methods
5. Determine an accurate vector of the spacecraft for propagating and future comparison with official tracking information (if released)

We plan to use beams from all the LOFAR international stations in France, Germany, Sweden and the United Kingdom and the Superterp to attempt beacon reception and the most accurate data possible for a multilateration (navigation) calculation.

We hope to be able to demonstrate reception and decoding of data from the spacecraft and, more importantly, determine the location of the spacecraft with orders of magnitude more accuracy that the COTS ground stations.

Comment: This article discusses use of the LOFAR system for multilateration of things in space. A similar LOFAR-like system can be used for multilateration location, tracking and control of drones, aircraft and other things in the close-earth atmosphere, in earth orbit, and coming into the atmosphere: meteorites, meteoroids, "space dust," etc. Here, the stations spaced far away (suitable for space multilateration), but for closer in multilateration, they would be spaced closer.

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Reference 7

PASSIVE METEORIC SYNCHRONIZATION OF TIME SCALES

Ivan E. Antipov, Veronika V. Bavykina, Yuriy A. Koval, and Goergiy V. Nesterenko, Kharkov State University of Radio Electronics (KTURE), Ukraine
33rd Annual Precise Time and Time Interval (PTTI) Meeting

Abstract. A special method that allows one to get time and frequency information without radio wave transmission at the secondary point is presented. This method can be used to receive time and frequency information that is contained in the TV signal by a meteor-burst channel.

At the present time, the most widespread and accessible method of time-frequency information transfer (among those using global longwave nets, meteor and satellite systems) is by television. * * * *

A signal from meteor trail arrives at each of the antennas with delays that depend on spatial position of each antenna. Using the information about the amplitude, phase, and delay time of signal- from each antenna, we can determine the angular coordinates of the meteor. * * * *

The radio wave reflection from meteor trails has been studied sufficiently well and is used for information transmission, and for precision time scale comparison. The precision time scale comparison by meteorburst channel is performed by the signal propagation time exclusion method - by sending of time signal parcel from the secondary clock standard to the point of the primary standard and its consequent retransmission backward together with the clock signal of the primary standard **[2].** This method is based on good reciprocity of the meteor-burst channel (equal time of straight and reverse signal propagation), and it allows synchronization with an error of about 1 ns [billionth of sec.]for distances up to 2000 km **[3].** However, to receive such a small error value, one needs sufficiently complicated receiving, processing and, what is very essential, transmitting devices in both points.

The synchronization of time and frequency standards by TV signals does not suppose a signal retransmission in the reverse direction, which is why we do not need to install the transmitting device at the point of the secondary clock. The capital TV centers transmitting the First Program of State Television with time and frequency signals have a sufficiently large power and work in a suitable frequency band (in Moscow on the first frequency channel, in Kiev on the second one, that corresponds to frequencies of 48 ... 66 MHz). This enables direct reception of these signals by a meteor-burst channel. Time-frequency information is contained in each frame of the TV signal and, consequently, is repeated each 20 ms.

Comment. This and following additional articles, graphs, maps and Comments all explain how TV VHF signals can be used in our planned pPNT-based networks.

Comment. This describes how TV channels in the low VHF range (30-70 MHz or so) can be received over a Meteor Burst (MB) signaling mode: that is, they reflect/ re-radiate off of MB plasma trails automatically- and can be received with a suitably tuned receive radio and high gain antenna. We plan networks of MB stations in the US with numbers and spacing to not need to use any TV signals in this range for time transfer functions (that are key to may functions if accurate enough, indicated in other slides herein): however, TV "signals of opportunity" can also be used, and improved with better timing at the TV transmitters: this use of TV station signal in the MB range will add accuracy, redundancy, and robustness. This will add little cost to the networks. This use of TV stations in MB receiver will enhance MB pPNT. See also following pages.

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Reference 8

ATDI advanced radiocommunications

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Latest News

TV or not TV? Radar is the question

Plotting aircraft positions with television signals rather than radar is an innovative idea now being discussed – and ATDI already has the tools to make it practical.

National Air Traffic Services (NATS) is looking into the feasibility of the concept through its Project PROVE (standing for Passive Radar Operational Viability Evaluation). NATS is testing a technique called multi-static primary surveillance radar and one of the organisation's system engineers Nick Young describes in his blog the principles underpinning the discussion: http://tinyurl.com/o4cku8s

The essence of the concept is that television signals bounce off metallic objects such as aircraft in flight in the same way that radar pulses do. Given geographically-separate receiving stations measuring the differing times of arrival of the reflected signal, the position of the aircraft can be calculated in a process called multilateration.

ATDI technical director Nick Kirkman comments: "I've been suggesting this notion to people for some time now. If it could ever be implemented, it would mean the liberation of some of the spectrum now being used by radars which is a thing that is attractive for a number of groups. The mobile phone networks are always clamouring for more frequencies and the government would greatly welcome the prospect of generating income by selling off spare spectrum."

He notes, though, that a multilateration system would also reduce the stealth capabilities of stealthy aircraft. "A stealth aircraft's small radar profile is produced by not only radar absorbing materials but also make sure that reflections from its surfaces are at different direction from the one they arrived from; in this way, a radar system in a fixed location does not receive the echo of the pulse it sent out. If television signals are used, multilateration means you can pick up all the reflected signals at a number of receiver points, not just the one from which they were generated."

Nick agrees with NATS' assessment that "there is still a long way to go before this could ever replace conventional primary radar" but points out that ATDI's flagship planning and modelling tool, ICS telecom, is ready for multilateration right now.

"ICS telecom has the functionality built into it," he says. "You can input the transmitter and receiver information and other data like latency jitter, sensor measurement errors and integration time and get a prediction for the signal strength, the estimated RMS error at a given location as well as horizontal and vertical dilution of precision and their standard deviations.

Comment. The above idea is not new as it suggests. However, this concept is based on terrestrial reception of TV "signals of opportunity" for mutilateration location. A problems is range of sufficient TV signals in VHF and UHF range for mutilateration, and that the angles of multilateration are often not very good for accuracy. In addition, the timing of the TV signals is not as great as in a dedicated multilateration systems where the fixed base stations transmit and/or receive the timed signals. A better method is what we plan, to use dedicated multilateration with terrestrial-wave and meteor-burst skywave propagation (in 40, 200, and 900 MHz) but also use the TV "signals of opportunity" for enhancements and redundancy. Some TV channels in VHF ranges can are reasonably close to our 40 and 200 MHz licensed spectrum, allowing shared components. See also above and following articles.

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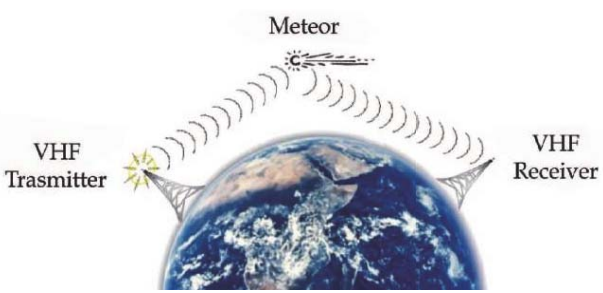
Radar Meteor Detection: Concept, Data Acquisition and Online Triggering

Eric V. C. Leite[1], Gustavo de O. e Alves[1], José M. de Seixas[1], Fernando Marroquim[2], Cristina S. Vianna[2] and Helio Takai[3]
[1]*Federal University of Rio de Janeiro/Signal Processing Laboratory/COPPE-Poli*
[2]*Federal University of Rio de Janeiro/Physics Institute*
[3]*Brookhaven National Labaratory*
[1,2]*Brazil*
[3]*USA*

1. Introduction

In the solar system, debris whose mass ranges from a few micrograms to kilograms are called meteoroids. By penetrating into the atmosphere, a meteoroid gives rise to a meteor, which vaporizes by sputtering, causing a bright and ionized trail that is able to scatter forward Very High Frequency (VHF) electromagnetic waves. This fact inspired the Radio Meteor Scatter (RMS) technique (McKinley, 1961). This technique has many advantages over other meteor detection methods (see Section 2.1): it works also during the day, regardless of weather conditions, covers large areas at low cost, is able to detect small meteors (starting from micrograms) and can acquire data continuously. Not only meteors trails, but also many other

The principle of RMS detection consists in using analog TV stations, which are constantly switched on and broadcasting VHF radio waves, as transmitters of opportunity in order to build a passive bistatic radar system (Willis, 2008). The receiver station is positioned far away from the transmitter, sufficiently to be bellow the horizon line, so that signal cannot be directly detected as the ionosphere does not usually reflect electromagnetic waves in VHF range (30 - 300 MHz)(Damazio & Takai, 2004). The penetration of a meteor on Earth's atmosphere creates this ionized trail, which is able to produce the forward scattering of the radio waves and the scattered signals eventually reach the receiver station.



Comment. See preceding pages and Comment.

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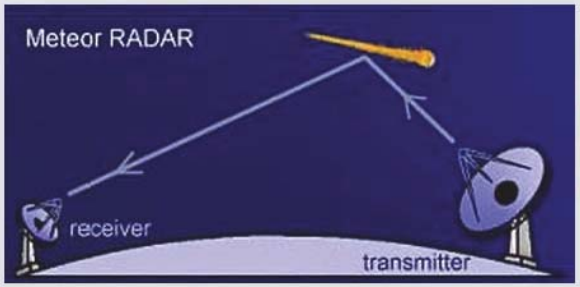
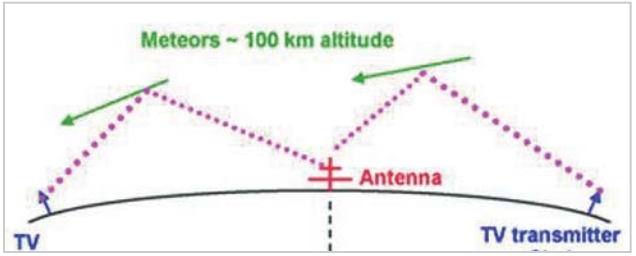
Outreach

FORWARD SCATTER METEOR RADAR



The Space Environments Team at NASA's Marshall Space Flight Center has developed a forward scatter radar system for the monitoring of meteor rates. Forward scatter radar has been used extensively for characterization of the meteoroid environment. The technique relies on the reflection of VHF signals from an over-the-horizon transmitter by the ionization trail of a meteor.

The MSFC meteor radar is tuned to 67.25 MHz, which allows the system to record echoes from an array of Channel 4 TV transmitters around the southeastern USA. All of the transmitters are over the horizon as viewed from the Marshall Space Flight Center, so it is normally impossible to detect them. The closest transmitters on this frequency are in Dothan, AL, Charleston, SC, Oak Hill, WV, Little Rock, AR, and Kansas City, MO. The map below shows local Channel 4 zero offset TV transmitters with a circle around each showing the areas they illuminate down to an altitude of 100 km (typical meteor altitude).



Comment: (continued from preceding pages). This is from a NASA website on meteor burst (MB) wave reception of TV signals in low band VHF (in this case, channel 4 in SE US). See preceding pages for our planned use of TV-signal MB wave applications.

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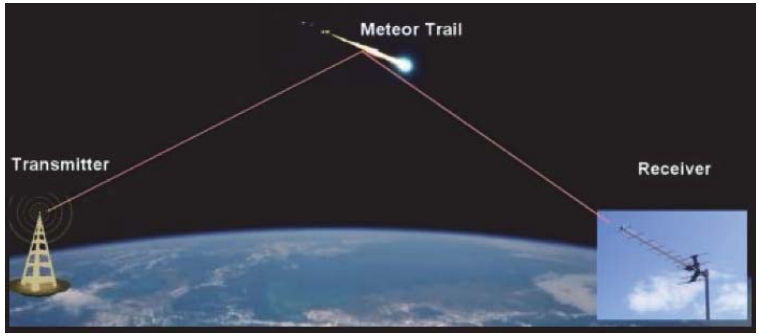
Reference 12

From: "Detecting meteor radio echoes using the RTL/SDR USB dongle," by Ciprian Sufitchi, N2YO. http://www.livemeteors.com/



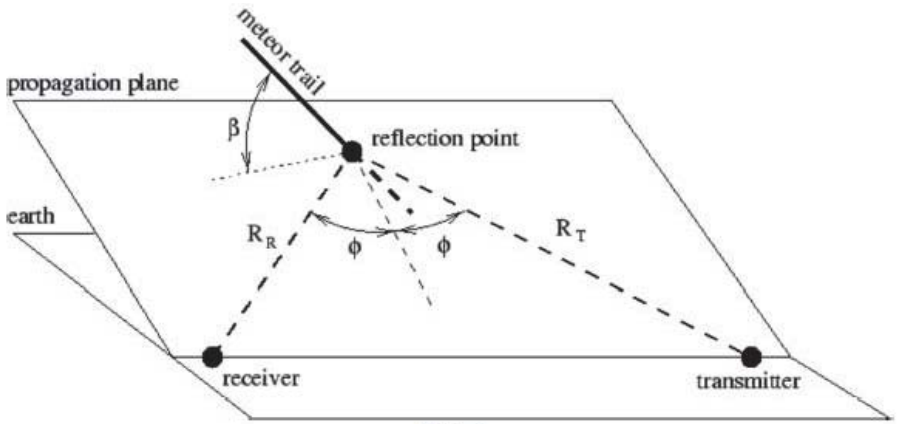


Fig. 2

If the radio waves from the transmitter reach the meteor trail …. [i]n forward-scatter, the transmitter and receiver are separated often by hundreds of kilometers or more, so the broadcast signal is reflected forward to the receiver from a meteor's ionization trail, which must lie somewhere between the two places.

The ideal source of radio signals in that band should be continuous and powerful. For many years the video carrier of analog TV transmitters has been the best choice for forward meteor scatter monitors, especially channels 2 – 5

CHBX-TV in Sault Ste. Marie, Ontario [above] transmitting on channel 2 analog TV 100 kW of power. To estimate the maximum range of a signal reflected by a meteor trail, one could resolve a simple geometry problem. The maximum distance would be:

Dmax = 2 R acos(R/(R+H)) [4] / R: Earth radius (6371 km) / H: Altitude of reflexion point (85…105 km)

The maximum theoretical distance to utilize a continuous transmitting tower for meteor scatter [burst] detection ranges between 2070 and 2300 km. If we consider a conservative distance of 2000 km around the CHBX-TV tower located in Sault Ste. Marie, Ontario, the area coverage could be plotted (Fig. 3). More than half of US states could benefit from this Canadian transmitter for meteor detection projects.

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ADVANCED MBRS re:
‘White Space’ Spectrum,*
Drones,
5G CMRS,
OAM Wireless, etc.

* Mostly Described above in the Spectrum section

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3. BENEFITTING APPLICATIONS

SNOW will be a natural fit for wide-area sensing applications where current WSN technologies have faced significant challenge. More importantly, it will enable an emerging class of large-scale wireless control applications that require real-time communication over wireless sensor-actuator networks.

3.1 Wide-Area Applications

Given its long communication range, SNOW will greatly simplify wide-area sensing applications that must collect data from sensors spread over a large geographic area or distance. With current short-range wireless technol-

5. CONCLUSIONS

Ubiquitous white spaces offer a new paradigm for wireless sensor networking to overcome the limitations on scalability and coverage. This paper has proposed Sensor Networking Over White space (SNOW) with the vision to supersede current wireless sensor networks and to unleash efficient WSN applications in cloud computing, cyber-physical systems, real-time applications, and remote monitoring. We present advantages, opportunities, and challenges in adopting SNOW with some potential proposals to overcome the challenges. We have opened a new door of research that will have tremendous impacts on the future of wireless sensing and control.

Comment. Licensed ~40 and ~200 MHz, with exclusive rights, higher power where needed, and full coverage, can be foundational spectrum onto which White Space spectrum in the same mid to low VHF range can be added, for greater capacity. This is similar to LTE-Assisted (or sometimes called LTE-Unlicensed) where unlicensed lower power spectrum near licensed LTE bands are combined, in LTE-Advanced multi-band (many non-adjacent bands) tech and service.

The article above describes one important use of lower-range White Space spectrum.

The arrangements described above will substantially advance the “Internet of Things” for critical infrastructure and services.

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Comment: This and following pages, concern drones and RTK (n-RTK when the n-RTK networks are available, as we can easily implement nationwide: the reference stations in large part already exist, and receiver cost is already low). N-RTK grade GPS-GNSS should be combined with the other pPNT methods available, including those described herein. Also, hovering drones can deliver N-RTK corrections, and can stay afloat with laser recharging (see above).

Launch: To launch the eBee RTK, shake it three times to start its motor, then throw it into the air. The artificial intelligence built into the senseFly autopilot continuously analyzes data from the Inertial Measurement Unit and the onboard GPS to control every aspect of its flight.

Monitor: Using eMotion ground station software you can view the eBee RTK's flight parameters, battery level and image acquisition progress in real time.

Control: Made a mistake with your planning? You can reprogram your drone's flight plan and landing point during its flight.

Process: Use Postflight Terra 3D professional photogrammetry software, supplied with every eBee RTK, to process your flight's photos into geo-referenced 2D orthomosaics, 3D point clouds, triangle models and Digital Elevation Models (DEMs), in just a few clicks.

Trust: With the eBee RTK's GSD of down to 1.5 cm, relative orthomosaic/3D model accuracy of 1-3x GSD, and absolute horizontal/vertical accuracy of down to 3/5 cm (without GCPs), you can have full confidence in the accuracy of the outputs you produce

Comment: This is a surveying fixed-wing drone. But all major drone use needs pPNT (precise position, navigation and timing) with the various pPNT methods described in part herein.

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Reference 19

NEW US PATENT FOR COOPERATIVE WIRELESS NETWORK INVENTION DIRECT APPLICATION TO MULTI DRONE DEFENCE CAPABILITIES LOWER POWER AND INCREASED BANDWITH FOR WIRELESS NETWORKS

Applications in the 3GPP LTE-Advanced standard, 4G and… "5G"wireless

The new US Patent 9136931…. The invention, "Cooperative Wireless networks" will provide an unprecedented increase in data bandwidth via radio networks, as well as having direct application to drone defence technology by dramatically enabling ad-hoc networks used to detect and communicate with airborne targets. It is related to earlier inventions by Mr. Shattil in the field of Cooperative MIMO technology that is also exclusively licensed to D13.

D13 CEO Jonathan Hunter said, "Coop MIMO technology is a hugely powerful tool to enable radio networks to work collaboratively between a variety of radio nodes, to improve bandwidth, and lower power requirements.

Instead of each receiver/transmitter having to take a divided share of the available signal, Coop MIMO technology enables radios to work together by exploiting mutual interference, and thus enhance capacity of radio networks".

Comment: This is one of many technologies and methods to combine terrestrial and airborne wireless, including for drones

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A Crucial Space Weather Effect: Meteors and Meteoroids

Lars Dyrud, Sigrid Close, Diego Janches, Meers Oppenheim, John Plane, John Mathews, Julio Urbina, Mihaly Horanyi, Jorge Chau, Jonathan Fentzke, Mike Sulzer, Sixto A. González, Shikha Raizada

At a **National Academies** webpage: Google the title or:

http://www8.nationalacademies.org/SSBSurvey/DetailFileDisplay.aspx?id=691&parm_type=HDS

Introduction

Every day billions of meteoroids impact and disintegrate in the Earth's atmosphere. Current estimates for this global meteor flux vary from 20,000-300,000 tons per year and estimates for the average velocity range between 14 km/s to 55 km/s….. These particles arrive both during intense showers and as a nearly constant rain of sporadic meteors. Understanding the interplanetary meteoroid environment is important for several fields of study from solar system evolution, upper atmospheric physics, planetary atmospheres and ionospheres, planetary geology, and most critically to accurately asses the risk that these particles present to manned and unmanned space flight. Yet, the basic properties of this global meteor flux…remain poorly constrained.

The largest uncertainties surround the most frequent meteors, mostly small (sand grain and dust size) sporadic meteors. We believe much of the mystery surrounding the basic parameters of the interplanetary meteor flux exists for the following reasons: the barely understood sampling characteristics of the different meteor observation techniques, and the scarcity of ground and spaced based measurements of meteors and interplanetary dust, which are used to derive or constrain most models.

* * * *

The last decade has seen a resurgence in US meteor research .... As a result, two new types of radar meteor reflections have become known and increasingly used. These reflections are known as meteor head echoes and non-specular trails and are largely observed and studied with high power and large aperture (HPLA) radars designed for incoherent scattering sensing of the ionosphere.....

These observations have also shown that these small dust and sand grain sized micrometeoroids are considerably more numerous than previously measured…. Additionally, it is becoming clear that observing radar meteors at two or more frequencies … yields much more information on the detail —e.g., meteoroid fragmentation....

* * * *

Recommendations

Because of the growing need from many within the Heliophysics and operational communities for an improved understanding of the interplanetary meteor and dust populations, we are strongly recommending funding for observations that support and constrain models of these populations. Further recognition of the interdisciplinary nature of this field of study via joint solicitations should also be prioritized in the coming decade.

1. In order to better understand meteor physics and to provide valuable observational constraints to meteoroid flux models, NSF should expand ground based utilities such as radars for observing meteors and meteoroids. This is necessary because each location and local time on Earth will preferentially view different sources of the meteoroid populations. Multi-frequency common-volume radars such as those available at Arecibo Observatory are particularly valuable. It is important to recognize that that while these large radars are typically funded from NSF Geospace Facilities section (formerly Upper Atmospheric Facilities) the value of meteoroid observations extends well beyond and includes planetary science and heliophysics as well.

The nationwide advanced MBRS described herein can contribute to meeting these Recommendations and important goals.
Other slides herein also comment on some of these goals.

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Critical technologies towards 5G RESEARCH RESULTS REPORT 24.9.2015

VTT Technical Research Centre of Finland Ltd is the leading research and technology company in the Nordic countries. We use our research and knowledge to provide expert services for our domestic and international customers and partners, and for both private and public sectors. We use 4,000,000 hours of brainpower a year to develop new technological solutions.

5.3 Secure communication using orbital angular momentum based radio

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Other contributing authors:
Tommi Dufva and Johan Sten

Need

The broadcast nature of the wireless communication medium makes it hard to eliminate unauthorized access to wireless networks. For that reason, it is relatively easy to eavesdrop or alter radio signals. In conventional communication systems, the protection of own information is usually achieved by obscuring the information transmission using cryptography, special modulation schemes such as spread-spectrum modulation, or both. However, security of wireless communication systems can be enhanced by using physical layer security extensions. One of such possible physical layer security extensions is the radio transmission using so-called orbital angular momentum (OAM) wave modes.

The classical manifestation of SAM is circular polarization of a radio wave. The classical manifestation of OAM is, however, a more quirky thing. Let us just say that each OAM wave mode generates a unique spatial distribution of the electromagnetic field and spatial distributions corresponding to different modes are orthogonal to each other. Under some specific conditions, these spatial distributions can be detected by specially designed parabolic or circular antenna arrays. Example radiation modes of the first six OAM wave modes are shown in Figure 1. Spatial dependence of the phase of the electromagnetic field is shown using different colours for different values of the phase.

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respective eigenvectors of a translation matrix. Furthermore, OAM wave modes form a set of additional independent parallel radio channels that can be exploited as additional degrees of freedom by the system designer. For example, they can be used to obscure information transmission by means of mode hopping. Nevertheless, there are certain limitations in using OAM wave modes.

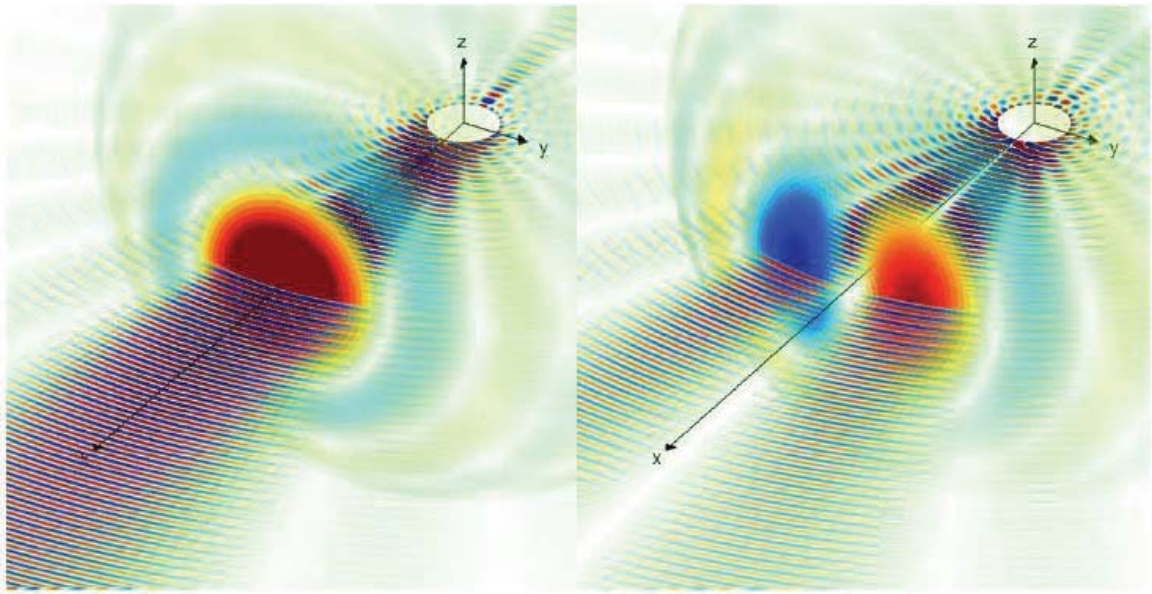

Fig. 1. Example OAM radiation modes: modes 1–2 in the left plot, modes 3–6 in the right plot.

Security benefits

The sensitivity of the channel orthogonality to a misalignments of the transmitter and/or the receiver and multipath propagation can be exploited to set up point-to-point secure radio links, for example tactical data links for Command, Control, Communications, Computers, and Intelligence (C4I) applications, which would be difficult to intercept and resilient to jamming.

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Angular Momentum of Electromagnetic Radiation

Fundamental physics applied to the radio domain for innovative studies of space and development of new concepts in wireless communications

Johan Sjöholm and Kristoffer Palmer

Uppsala School of Engineering
and
Department of Astronomy and Space Physics, Uppsala University, Sweden

May 2, 2007

OAM has so far not been used to its full extent—if at all—in the radio domain, except for some proof-of-concept experiments in the microwave range. As will be described in this thesis, the advent of fast analog-to-digital and digital-to-analog converters has made it possible to construct combined 3D sensing antenna and tri-channel digital receiver systems which can measure coherently the instantaneous 3D field vector, a first-order quantity, of an EM signal in the radio domain. This new possibility enables the processing of EM field vectors, including OAM encoding and decoding of radio beams, with high precision and speed under full software control. This is in contrast to optics where detectors are still incoherent, capable of measuring second (and sometimes higher) order field quantities only and not the field vectors themselves. In order to cover

new unexplored ground and find additional uses of electromagnetic fields, these full vectorial properties of the EM field, and their *physical* encoding, have to be explored. We think that therein lies the future for a more efficient use of electromagnetic fields and improved radio methods for research and communications [8, 20]. This is what this thesis is about.

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8.1.1 Self-calibration of ionospherically aberrated radio signals

It is well-known among radio astronomers and space physicists that turbulence in the ionospheric layers can significantly alter the characteristics of radio signals that pass through them, even if the frequency of these waves (10–100 MHz) exceed the critical frequency of the ionosphere (3–10 MHz) by quite a bit. Part of the radio signal aberration (and scintillation) are amplitude and phase changes caused by the ionospheric turbulence. The self-calibration technique, developed in the radio astronomy community, manages to reduce these aberrations significantly. In this technique, a radio map of known radio objects (Cass-A, Crab, Cygn-A, *etc.*) are used as calibrators to iteratively adapt parameters of a model so that the radio interferences are eliminated.

The correction algorithm used at LOFAR (and tried at LOIS), is based on an empirical model where correction parameters are applied dynamically to the raw, sampled radio signals in a control loop manner to minimize the disturbances. The self-calibration process data can serve two purposes. It can be used for correcting signals received so that the information about distant objects is accurate. At the same time the self-calibration data provide valuable information about the dynamics of the Earth's ionosphere, which is of high interest in space physics research [50]. Similar self-calibration techniques can be envisioned to be used to compensate for imperfections in satellite-based navigation systems caused by ionospheric turbulence.

For low-frequency radio telescopes such as LOFAR, the self-calibration procedure must be repeated several times per minute. Figure 8.3 shows the difference between an un-calibrated (left) and calibrated (right) image of an astrophysical

OAM use at LOIS, part of LOFAR, in 10-70 MHz (including ~40 MHz) to increase performance. OAM will better enable radio detection of the nature and changes in Ionospheric plasma. This will improve weather prediction, and GPS-GNSS accuracy.

For essentially the same reasons, OAM will increase performance of MBRS which uses meteor burst plasma trails to "reflect" (re-radiate, in most cases) signals back to earth.

As Russian papers show, real time detection of the status and changes in the Ionosphere will improve MBRS timing, which can be more accurate than GPS/ GNSS timing.

MBRS (and other Ionospheric radio systems) use of OAM uses LOS propagation, from and back to a to the Earth with nothing in the way, and also uses sophisticated antenna arrays: these make OAM work well, since the antennas can be have the complexity, orientation, and size needed for practical radio OAM.

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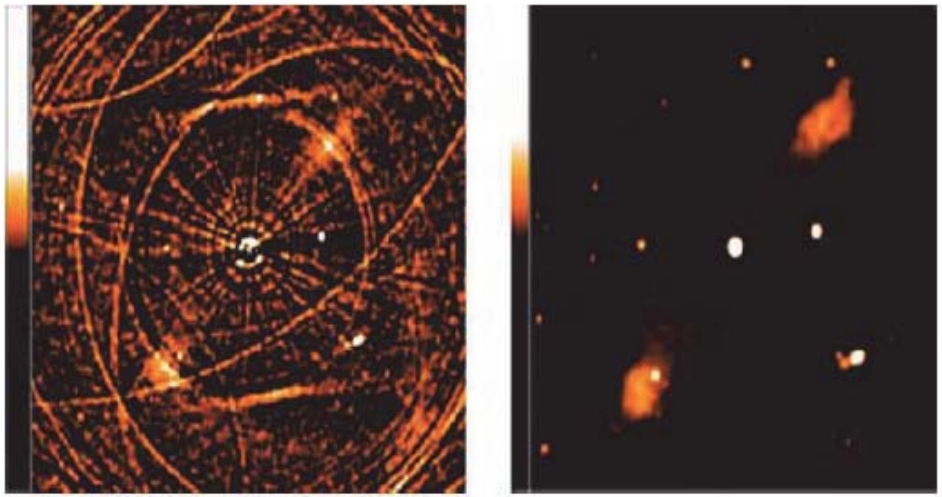

Figure 8.3:
Example of how a self-calibration procedure can reduce radio image aberrations caused by ionospheric intensity and phase distortions. The left-hand panel shows the image before the self-calibration, the right-hand panel after. The radio image data were taken at the NRLNRAO 74 MHz Very Large Array radio telescope near Socorro, NM.

We expect that a self-calibration that also corrects for polarization and vorticity distortion, based on the LOIS vectorial radio field technique, utilizing OAM, will be able to improve the results considerably, particularly at low frequencies.

object observed at 74 MHz by the NRL-NROA VLA radio telescope: In the left panel the aberration of the ionospheric turbulence is clearly seen, while in the right panel, the self-calibration procedure has cleaned the radio image quite considerably.

However, also the radio beam angular momentum (wave polarization and vorticity), which carries important information about the radio object under study, can be significantly influenced if the beam propagates through distorting media such as a turbulent ionosphere [21]. These aberrations have to be compensated for in order to obtain reliable data about the radio source under study. The vectorial sensing technique developed at LOIS and described in this thesis, makes it possible to extend the self-calibration technique to handle also vorticity distortion.

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Diplexers Shrink to Meet Complex Multiband Wireless Needs

By Bill Schweber. Contributed By Electronic Products. 2015-02-26

As multiband smartphones, which must support different frequency bands, become more common, the diplexer is an increasingly important passive component. This multiband bandpass filter is placed between the antenna and the electronics of the wireless unit, allowing multiple transmit power amplifiers and receiver front-ends to support the different bands yet share a common antenna path.

On the receiver side, the diplexer takes two signals from the antenna (often called high- and low-band signals) and directs them to the appropriate receiver front-end; on the transmit side, it combines the signals from two output power amplifiers in different bands before they go to the antenna (Figure 1). The technology and associated implementation of modern diplexers is closely related to SAW filters and other monolithic, solid-state filters.

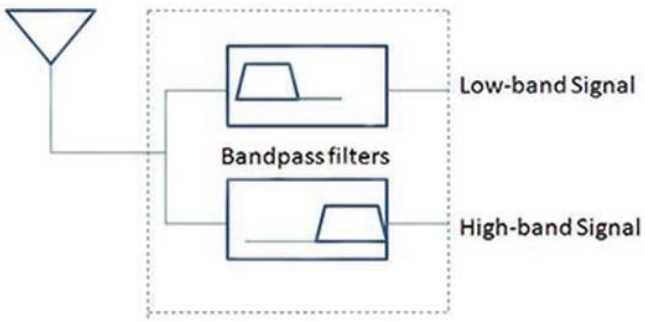

Figure 1: A basic diplexer consists of co-packaged low- and high-band bandpass filters, to split/combine two adjacent bands so they can share a single antenna.

From: http://www.digikey.hk/en/articles/techzone/2015/feb/diplexers-shrink-to-meet-complex-multiband-wireless-needs

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lvGWRS Technology and Inetegration – v1.0

Low VHF Ground Wave Radio Service & Integration with Advanced MBRS for ipPNT

* Mostly Described above in the Spectrum section

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Low VHF Ground Wave Radio Signaling Networks

This slide is also near start above. See the full article for more.

Low VHF Channel Measurements and Simulations in Indoor and Outdoor Scenarios

by F T Dagefu, G Verma, C R Rao, P L Yu, J R Fink, B M Sadler, and K Sarabandi, Computational & Information Sciences Directorate, ARL | K Sarabandi Dept of Electrical Engineering and Computer Science, University of Michigan

ARL

US Army Research Laboratory

The lower VHF band has potential for low power, short-range communications, as well as for geolocation applications, in both indoor and urban environment.... both line-of-sight (LOS) and non-LOS (NLOS) cases.... [T]he measured channels have a nearly ideal scalar attenuation and delay transfer function, with minimal phase distortion. Compared with higher VHF and above, the measured short-range VHF channels do not exhibit small-scale fading, which simplifies communications receiver signal processing, and enables phase and amplitude based geolocation techniques.

The lower VHF band... scatterers are small in terms of wavelength.[ ] Consequently, strong penetration through multiple walls and buildings can be achieved at relatively low power. Reflection, scattering, and diffraction phenomena are dramatically reduced, thereby greatly minimizing multipath fading, yielding a short-range channel that is LOSlike in terms of very slight phase distortion and delay spread. This liberates the system designer at low VHF from the typically stringent requirements on power, system bandwidth, and complex equalization processing needed in ultra-high frequency (UHF) and microwave based systems....[D]ue to recent advances in antenna miniaturization techniques and the development of palm-sized lower VHF antennas with good performance,[ ] interest in low power, low data rate communications in this band is increasing.... [I]n North America, there is a dual allocation at low VHF..... [T]he primary allocation near 38 and 40 MHz is for Federal use.... The simplicity of the channel, along with recent advances in the design of extremely miniaturized lower VHF antennas, can be exploited in a large variety of signal processing and communications applications including geolocation in GPS-denied environments and... in search-and-rescue operations.

Fig. 8 ... view of the test facility. *P0 and P1 are the 2 transmitter* positions and *R0 to R9 are various indoor and outdoor regions traversed by the robot* for data collection

Published online by ARL. Also in: IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 63, NO. 6, JUNE 2015

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A Sub-wavelength RF Source Tracking Device for GPS-denied Environments

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A Sub-wavelength source tracking system utilizing highly miniaturized antennas in the HF range for applications in GPS-denied environments such as indoor and urban scenarios is proposed. In order to track a source in such environments, a radio triangulation approach that combines directional finding and interferometry approaches is pursued.

A low-profile and highly miniaturized antenna (with λ/300 height and λ/100 lateral dimensions) designed to efficiently generate omnidirectional, vertically polarized field is utilized.

At such low frequencies the phase difference between the signals at the Rx antennas (an important quantity of interest), is too small to be accurately measured. To address this issue, a biomimetic circuit that mimics the hearing mechanism of a fly (Ormia Ochracea) is utilized. With this circuit, very small phase differences are amplified to measurable values....

The ability to accurately detect the direction of arrival and track the location of a source in complex and GPS-denied environments is useful for a wide variety of applications such as fire and earthquake rescue missions, user position estimation in mobile communications and for security systems...[,] real time positioning and tracking of robotic platforms that are used to enhance tactical situational awareness in complex environments including urban and indoor scenarios...[, and] high-resolution navigation in these cluttered environments. ...

[T]he level of multipath increases with frequency making the task of tracking the source very challenging. To minimize these effects, the use of miniaturized antennas operating in the HF range is proposed.... [*]

The advantage of using such low frequencies is that scattering from walls ceiling and furniture will be small compared to the direct path....

In this paper, a radio triangulation approach that combines directional finding and interferometry based on measurements from at least two known locations is proposed.

To determine the direction of arrival, the phase and magnitude of the received electric field are utilized. Furthermore, by measuring the direction of arrival at multiple points, the location of the source is retrieved using triangulation....

[*] The center frequency [in]... this simulation is 23MHz.