BEFORE THE

NATIONAL TELECOMMUNICATIONS INFORMATION AGENCY

WASHINGTON DC 20230

| | |
|---|---|
| Developing a Sustainable Spectrum Strategy for America's Future<br><br>Request for Comments | Docket No. 181130999–8999–01<br><br>RIN 0660–XC044 |

COMMENTS OF THE POLARIS PNT GROUP [1] / [2]

MARCH 16, 2019

The Request for Comments ("RFC")[3] seeks comments on:

The National Spectrum Strategy ... to

(a) Increase spectrum access for all users, including on a shared basis, through transparency of spectrum use and improved cooperation and collaboration between Federal and non- Federal spectrum stakeholders.

(b) Create flexible models for spectrum management.

(c) Use ongoing research, development, testing, and evaluation [RDT&E].

(d) Build a secure, automated capability to facilitate assessments.

(e) Improve the global competitiveness of United States terrestrial and space-related industries and augment the mission capabilities of Federal entities through spectrum policies, domestic regulations, and leadership in international forums.

The Space Policy Directive-3 ... considerations:

- consistency between ...national and international regulations and goals ...in, the RF spectrum for space services.
- advantages of addressing spectrum in ...STM [Space Traffic Management].
- flexible spectrum use and ...emerging technologies for...space systems.
- spectrum-dependent STM components, such as inter-satellite safety communications and active debris removal systems.

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1 To National Telecommunications and Information Administration, U.S. Department of Commerce, 1401 Constitution Avenue NW, Room 4600, Attn: John Alden, Washington, DC 20230. This is emailed to: *spectrum-strategy-comments@ntia.doc.gov.*

2 Re 'Polaris' - see signature page below. / These Comments are limited to public information.

3 In the Federal Register, Vol. 83, No. 245, Friday, Dec. 21, 2018, Notices.

1. The POLARIS PNT GROUP (or POLARIS PNT) listed on the signature page below, is involved in many of the matters in the subject NTIA RFC as listed above. This is shown at http://www.polarispnt.space/. This site has embedded PPT PDF files with details and citations to papers on technology and systems. These are attached as Exhibits 1 to 3.

2. In brief, radio-based systems for communication, location, and remote sensing have to date dealt mostly with terrestrial systems with, relatively, only a scattering of earth atmosphere and space systems. However, there is a compelling case for radio-based systems for the latter as POLARIS PNT summarizes in this website.

Because these are mostly new, the site and the 3 Exhibits from it contain (A) broad concepts and longer-term projections, and (B) closer-in developments, technologies and systems.

(A) Broad concepts and longer-term projections (from Exhibit 2):

- 3D Radio Systems. 3D- use of Earth's ionosphere-plasmasphere-magnetosphere (3D IPM) Using radio frequency transceiver phased arrays with facilities similar to the radio astronomy LOFAR and SKA for both space and atmosphere science, RF systems (enhanced broadband meteor burst centric), sub-nanosecond time synchronization and encryption, augmentation, via:
- Facilities 1: Phased arrays, mini-SKAs, timed for dual earth/ astronomy radio functions. Terrestrial and high seas (F1).
- Facilities 2: Extensive private-facility rooftop stations combining solar-energy panels and RF transceivers (F2).
- F2 distribution: Any stores, utilities, nonprofits, and 'amazons'.
- Tech, e.g., Eastlund US2007 patent 0238252A1 (method and apparatus for altering a region in the earth's atmosphere, ionosphere, and/or magnetosphere); A. Streltsov: *Energy from Space Plasma*; and Whistler waves' to protect communications from nuclear blast. https://laserearthshield.info; Plasma and rf-laser transducer antennas in personal & IOT devices. (Other not herein.)

(B) Closer-in developments, technologies and systems (from Exhibit 3)

- Advanced Continental Low-VHF 20-55 MHz Meteor Burst Radio Signaling Networks (MB) (MBRS) and Low VHF Ground Wave Radio Signaling Networks (lvGWRS) -- For critical infrastructure & services, including:
- MBRS: for broadcast data (for N-RTK for GNSS-GPS high accuracy; other), 2-way communications, MB positioning navigation & timing (GPS *independent*) ("iPNT"), MB encryption, atmospheric science and prediction...
- lvGWRS: for best, low interference and attenuation, LOS & NLOS networks in urban and indoor iPNT and low-rate networks for geolocation, ground drones, search & rescue, smart cities and buildings.

- Overall: Advanced MBRS, as indicated herein, can provide highly cost effective and critical benefits to the nation.

Advanced Meteor Burst Radio Signaling

- Billions of small meteoroids enter the atmosphere daily, few large enough to be visible, and create no- cost, ever-renewed, smart, plasma antenna arrays in the sky, responsive to VHF 20-55 MHz.
- With new radio, antenna and computer techniques, this will enable ‘4G’ and ‘5G’ Meteor Burst Radio Signaling services that are robust, secure, continent wide with no coverage gaps, at low-cost-of-coverage.
- It will deliver n-RTK for precision GPS nationwide.
- It will provide Position, Navigation and Timing services independent of GPS and far more secure from sky or terrestrial attacks.
- It will improve atmospheric and weather science that is much needed, and provide other major benefits.
- NTIA and FCC spectrum is available (see Exhibit 3) and is little used.
- Reception of the many key data services will be via one-way broadcast, receivable in any radio device, even consumer smart phones.

The above-referenced B. Eastland patent (see ¶4 below) indicates, among other developments (some not disclosed herein) how advanced MBC - MBRS as outlined in Exhibit 3 can be used to *greatly enhance*:

- *Terrestrial* 5G wireless in *urban to remote* areas -- and lower overall ambient RF levels and "pollution."
- *Earth atmosphere and space* radio communications, science and probes.
- *Substantially reduce greenhouse gases* in Earth's atmosphere layers.
- Other critical and economically viable systems and services.

3. The better known components indicated above include “Meteor Burst Communications” in low VHF ranges (approx. 20-55 MHz) (“MBC”). In the US, this is extensively used by the US DOA for its “SNOTEL” and “SCAN” systems. (See Exhibit 3 at p, 23 et seq.) These are narrowband and low bandwidth systems, sufficient for the purposes. However, far more advanced high capacity MBC is feasible and planned by POLARS PNT, and is described at the above website (and in Exhibit 3, from the site).

4. From the Eastland Patent, above: US2007/023825[4] (emphases added):

> Abstract. This invention is a method and apparatus for creating artificially ionized regions in the atmosphere utilizing ionization trails of cosmic rays and

[4] Copy at: https://patents.google.com/patent/US20070238252A1/en

micro-meteors to ignite plasma patterns in electric field patterns formed by ground based electromagnetic [phased array] wave radiators. The applications are useful for telecommunications, weather control, [and]... protection and defense applications. The invention lowers the power requirements for forming artificial ionized regions in the atmosphere by a factor of up to 1600 times lower than those required in existing designs and projections for creation of artificial ionized regions in the atmosphere.

[00116] A principal embodiment is to use cosmic particles, such as ... micro-meteor trails, to ignite an artificial ionized region "plasma pattern" in the air....

[0022] Another... is to enhance cellular communication systems by producing disc shaped plasma patterns at altitudes of at least 10,000 meters over one or more existing cellular communications towers.

[0023] Another...is to provide a short haul cellular telecommunications systems by producing disc shaped plasma patterns at altitudes of at least 10,000 meters and the use of at least one cellular base station with an upward pointing antenna.

[0024] Another ...is a city wide cellular communications system by producing a disc shaped plasma pattern at altitudes of at least 30,000 meters and the use of at least one cellular base station with an upward pointing antenna. Another principal embodiment of this patent is to provide a strong signal for city wide cellular communication by producing five disc shaped plasma pattern in a roughly parabolic pattern at an altitude of at least 30,000 meters and the use of at least one cellular base station with an upward pointing antenna. The additional gain provided by this system could make it possible to provide very high data rates to cellular equipment, possibly giving a WI FI connection to a whole city.

[0025] Another...is to provide a long haul communication system by erecting shaped plasma patterns at two different locations on the earth's surface, each pattern located at an altitude of 80,000 meters and to use a base station at each location to send and receive telecommunications signals.

[0026] Another... is a portable system for city wide communication. The individual phased array radiating elements have the capability to vary the frequency and phase of the electromagnetic wave generator and to point the electromagnetic radiation in the proper direction. Such a system would be useful ... in natural disasters.

[0027] Another ... is to ... create the plasma layer to accelerate electrons on the surface of the plasma layer to high energy... for communications or military applications.

[0028] This invention makes practical many applications that derive from production of plasma patterns in the air.

5. The POLARIS PNT entities and work is based on involvement in wireless expanded to GPS-GNSS and other radio-based systems -- all still in early phases verses capabilities.

Forms of "3D Radios Systems" -- "use of Earth's ionosphere-plasmasphere-magnetosphere (3D IPM)" as outlined above and described further in the 3 Exhibits hereto, can substantially enhance radio science and systems in the nation, and thousands of miles beyond the nation's territorial limits, for many critical applications of federal agencies and the general public.

The United States began the GNSS with GPS and has been the world leader. US DOC and NTIA play major rules, e.g., https://www.gps.gov/governance/agencies/commerce/. The matters herein are in accord and can enhance developments and success in these and many other critical radio-based systems of many kinds.

The undersigned has net with the GPS office at DOC, NTIA OSM at DOC, some agencies' wireless program offices, and DARPA over the last several decades on matters leading to those summarized herein. The undersigned also arranged for funding and contributions to University of California studies related to these matter.[5]

The undersigned also met with the FCC on these matters also, and a plan to "migrate" (under existing law and precedent) certain radio spectrum now under FCC domain to, or primarily to, NTIA OSM domain on behalf of US agencies that may work with the public-benefit programs of the POLARIS PNT entities on matters outlined herein. In this regard, *the FCC does not have the capabilities, interest or patience, for these matters and even works against* these the undersigned worked on for over a decade including on a non-profit bases.[6]

*However, other federal agencies* who can use or may use advanced systems and services outlined herein for their own use, and in part host or may host them for broad commercial uses, with various forms of "sharing," should have the *capabilities, longer-term plans and programs, ample spectrum rights and much if the infrastructure needed.*

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[5] See https://people.eecs.berkeley.edu/~kannanr/assets/project_loc/CHALOCBA.pdf

[6] The same applies to certain State of California authorities. Both are easy to show. The undersigned is proceeding with FCC, judicial, ADR, Congressional, and other remedies,

Respectfully submitted,

POLARIS PNT GROUP - [7]
Polaris PNT PBC
Polaris PNT 1, PB LLC
Polaris PNT 2, PB LLC
Polaris PNT 3, PB LLC

By:

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Berkeley, CA 94704
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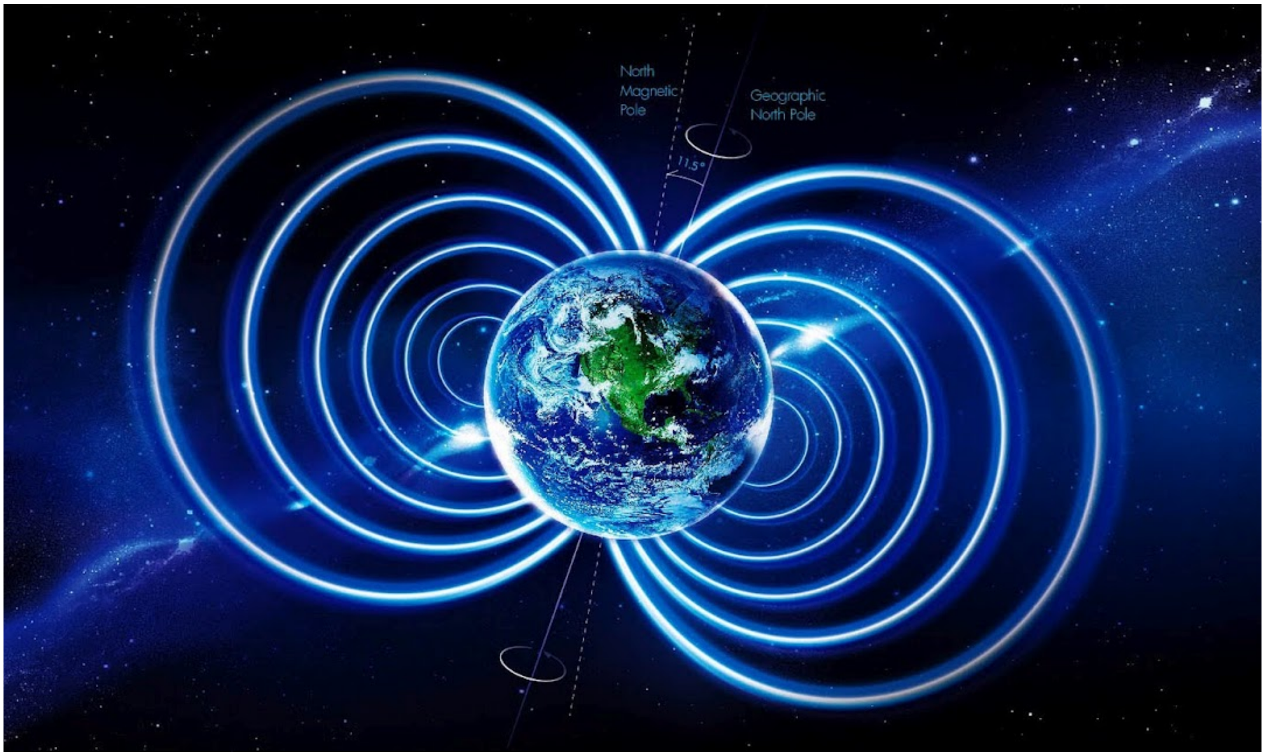
3 EXHIBITS

[7] Delaware statutory public-benefit companies (for private profit and public benefit).

# EXHIBIT - 1




The Earth is a spinning magnet and with the Sun form a radio-magnetic- plasma- electric system active above the Earth's surface in the coupled ionosphere and magnetosphere.

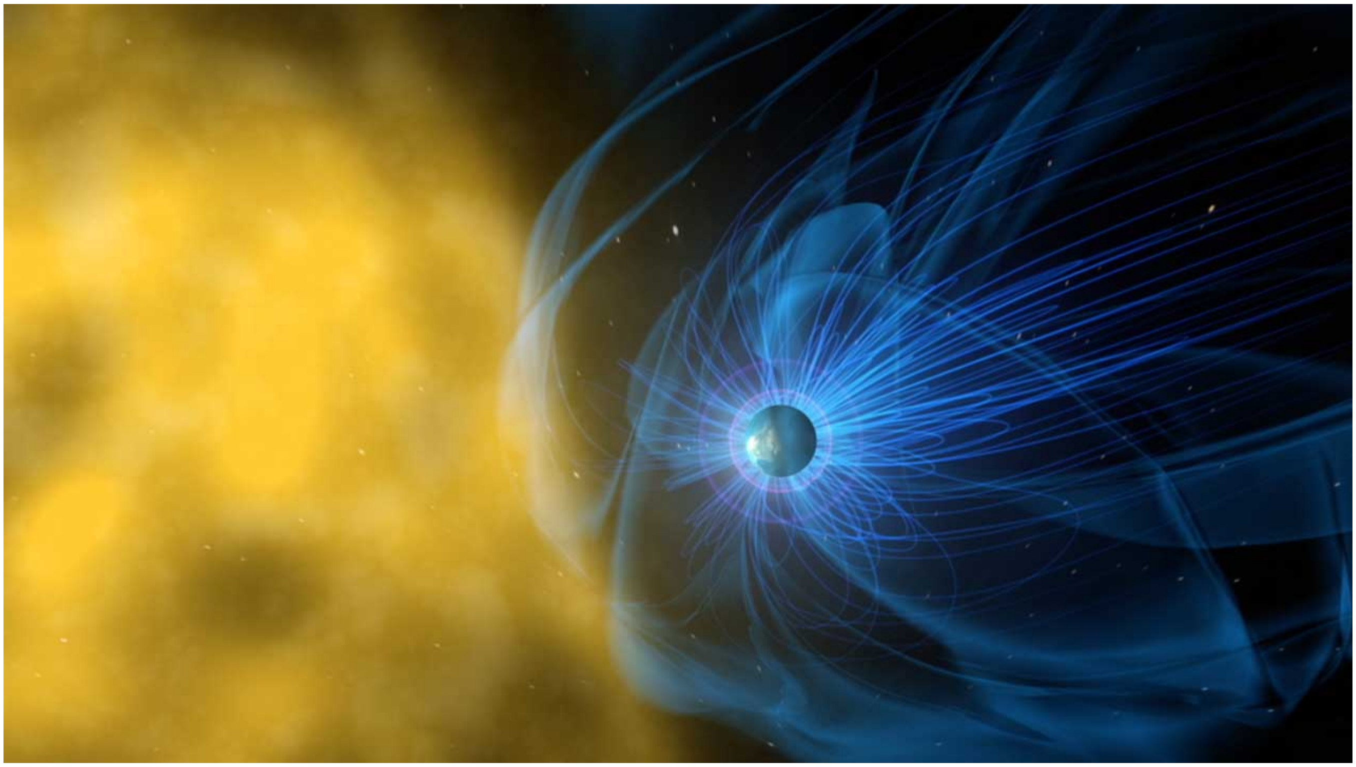
This can be harnessed for the energy needed for civilization; for long range high capacity communications including a new generation and configuration of global Internet; to advance and protect global "free speech" and online education, arts and sciences; to scrub the atmospheric layers of many greenhouse gasses; to beneficially modify weather and climate and improve forecasting; for distributed phased radio astronomy, supercomputing and encryption with a growing global instrument; and for other critical applications.

This can be implemented to a large extent by private individuals and companies and coordinated by nonprofit foundations using open technologies.

Research and systems for the main components needed exist at least in viable first generations. Documents at this website show some of these.

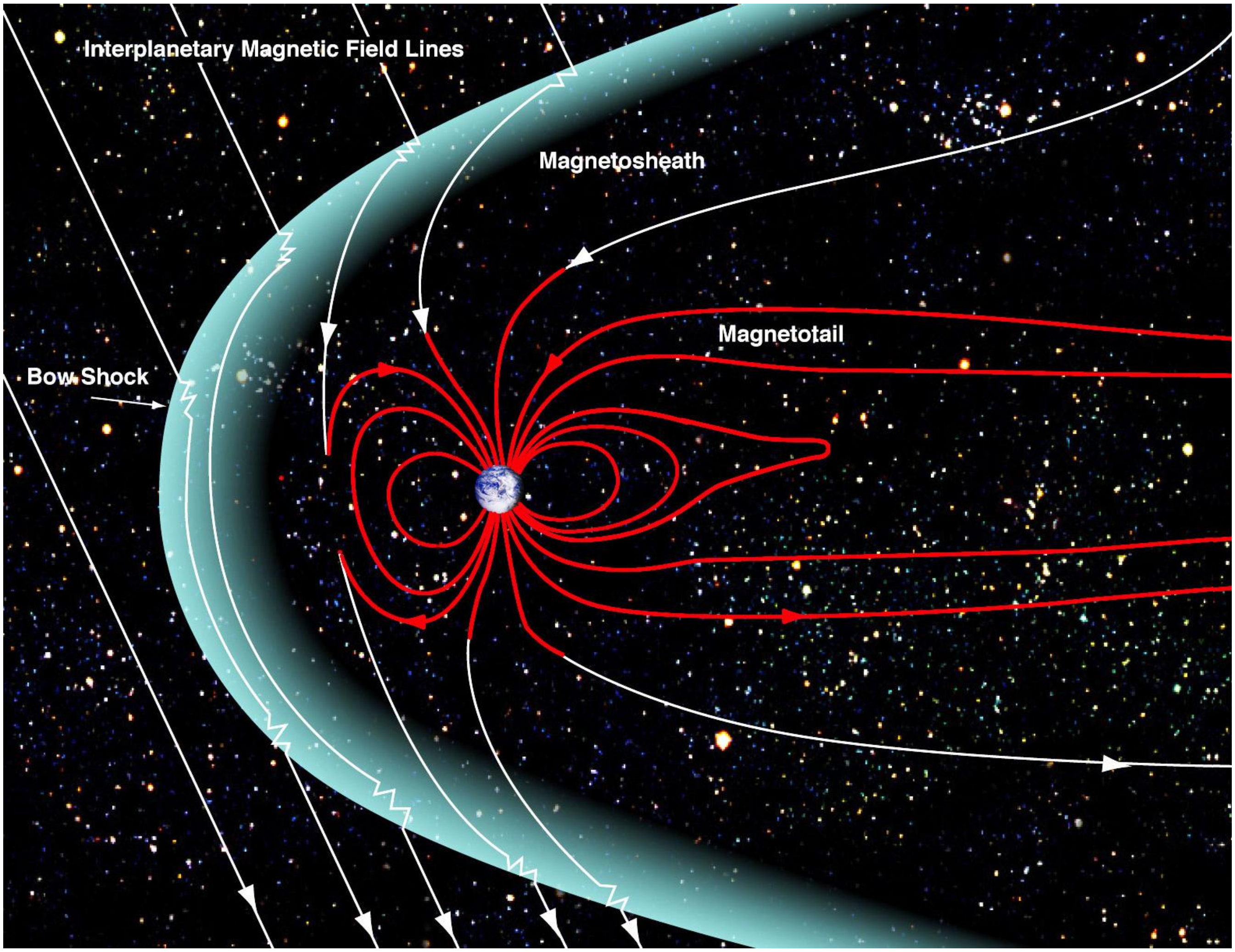
NASA SCIENCE
SHARE THE SCIENCE
Science Topics

# Magnetospheres

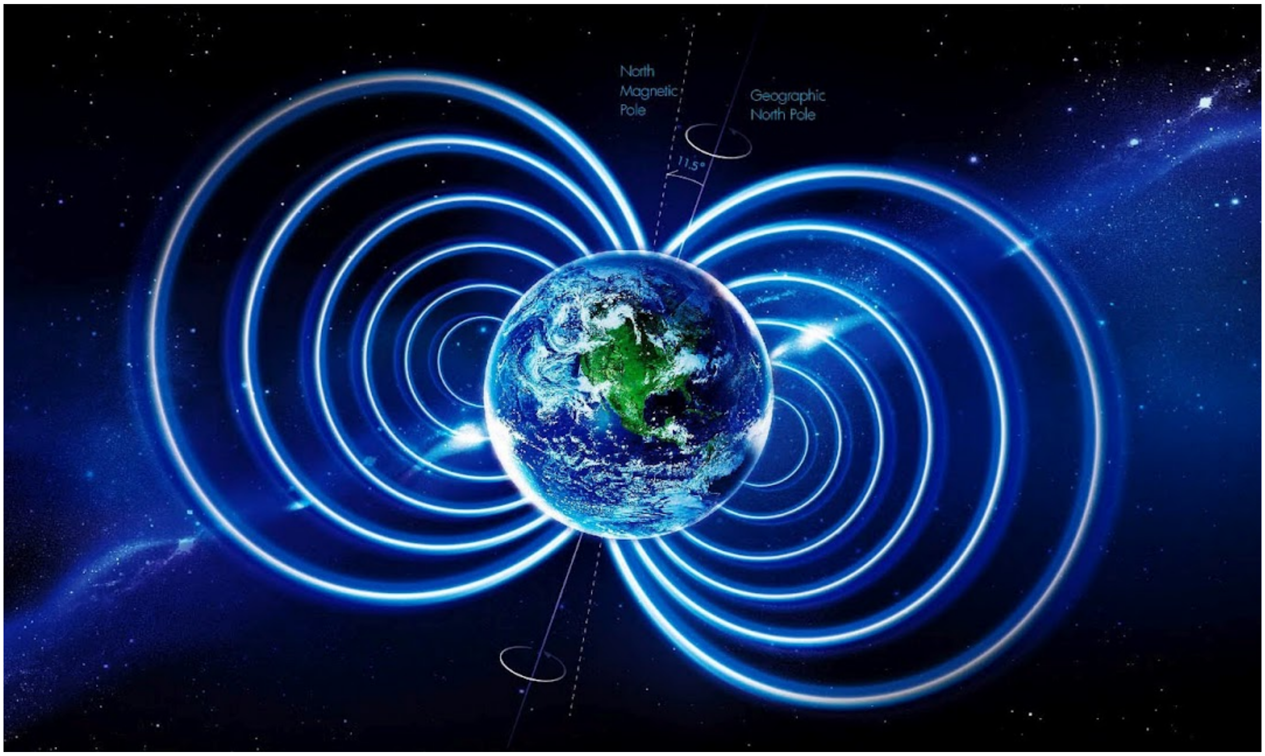


Earth is surrounded by a giant magnetic bubble called the magnetosphere, which is is part of a dynamic, interconnected system that responds to solar, planetary, and interstellar conditions.

A magnetosphere is the region around a planet dominated by the planet's magnetic field. Other planets in our solar system have magnetospheres, but Earth has the strongest one of all the rocky planets: Earth's magnetosphere is a vast, comet-shaped bubble, which has played a crucial role in our planet's habitability. Life on Earth initially developed and continues to be sustained under the protection of this magnetic environment. The magnetosphere shields our home planet from solar and cosmic particle radiation, as well as erosion of the atmosphere by the solar wind - the constant flow of charged particles streaming off the sun.




Earth's magnetosphere is part of a dynamic, interconnected system that responds to solar, planetary, and interstellar conditions. It is generated by the convective motion of charged, molten iron, far below the surface in Earth's outer core. Constant bombardment by the solar wind compresses the sun-facing side of our magnetic field. The sun-facing side, or dayside, extends a distance of about six to 10 times the radius of the Earth. The side of the magnetosphere facing away from the sun - the nightside - stretches out into an immense magnetotail, which fluctuates in length and can measure hundreds of Earth radii, far past the moon's orbit at 60 Earth radii.




The following pages in black and white (some coloring reset) are from: "HAARP, research and applications: a joint program of Phillips Laboratory and the U.S. Office of Naval Research, January 1, 1995." We are not a government entity and have different applications and systems in mind, but aspects of this US report are useful to show some of the physical systems involved, and some techniques.

This should be read with other documents at this website.

The Nordic-nations "EISCAT 3D" project is designed to exceed HAARP in various ways (however, HAARP may be enhanced, as well). See, e.g.. next page.

[Continued re EISCAT 3D]  See, e.g.,

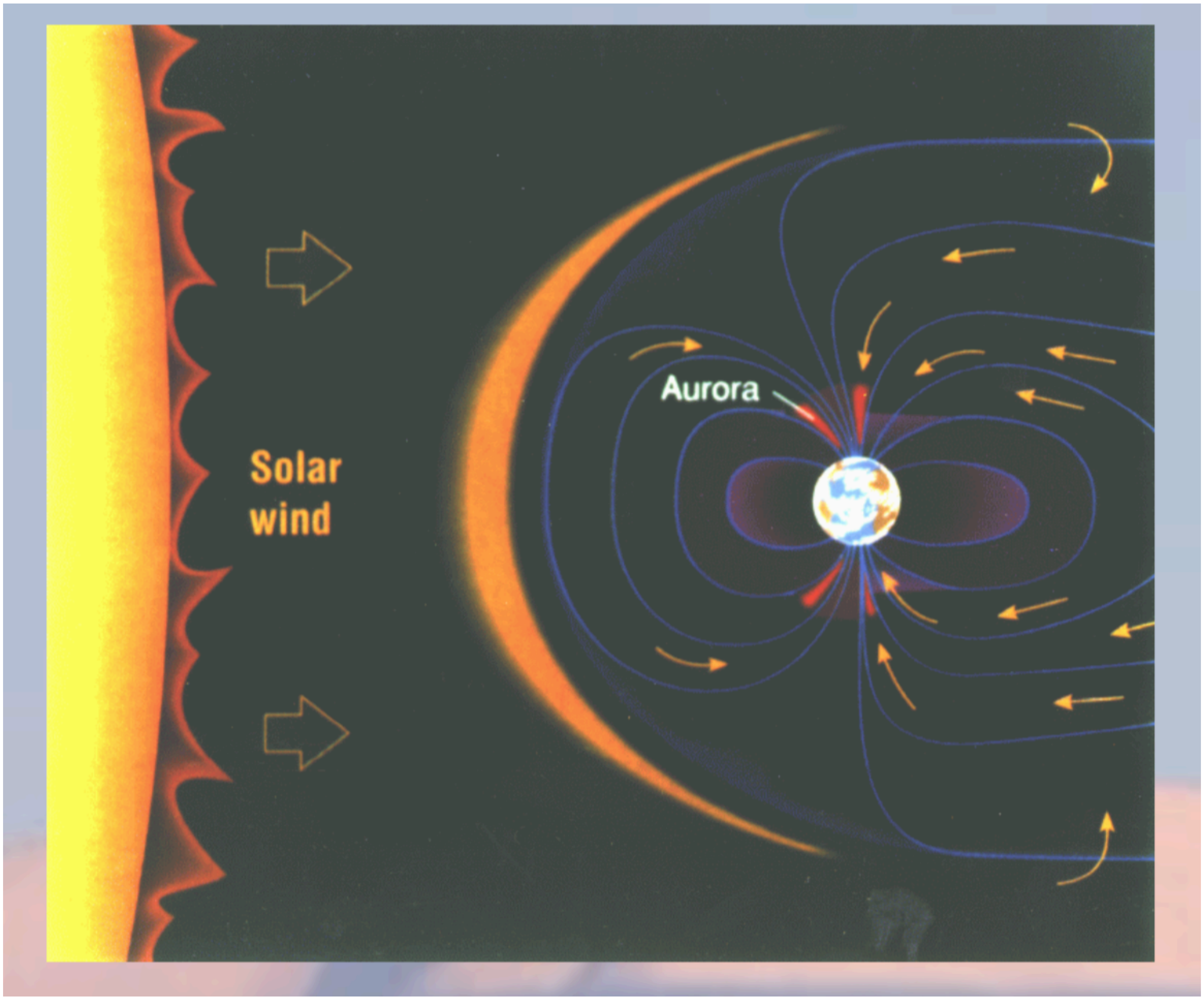
https://www.eiscat.se/eiscat3d/

https://www.eiscat.se/eiscloud/index.php/s/XH2Y3mQeXat5wdW?path=%2FPublicity%20material#pdfviewer  --

"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, which then finally would have a joint science programme directed to the most relevant science questions," says Turunen. The joint instrument and programme mentioned would require possible modifications to the training regimen for future radar scientists, as it requires them to work on a more global scale and with global data. With this in mind, Turunen and his partners are already looking towards organising global incoherent scatter radar schools along with colleagues from the U.S.

"Because of EISCAT_3D's dedication to international collaboration, the project has been invited to participate in science and political discussions by the EU and the [U.S.] National Science Foundation ["NSF']. The two organisations are currently in talks to determine ways to jointly advance and finance the development, operation and use of large-scale research infrastructures."

The above indicates, EISCAT 3D's international nature.  This may involve with US private non-governmental entities as well as US government entities such as NSF.



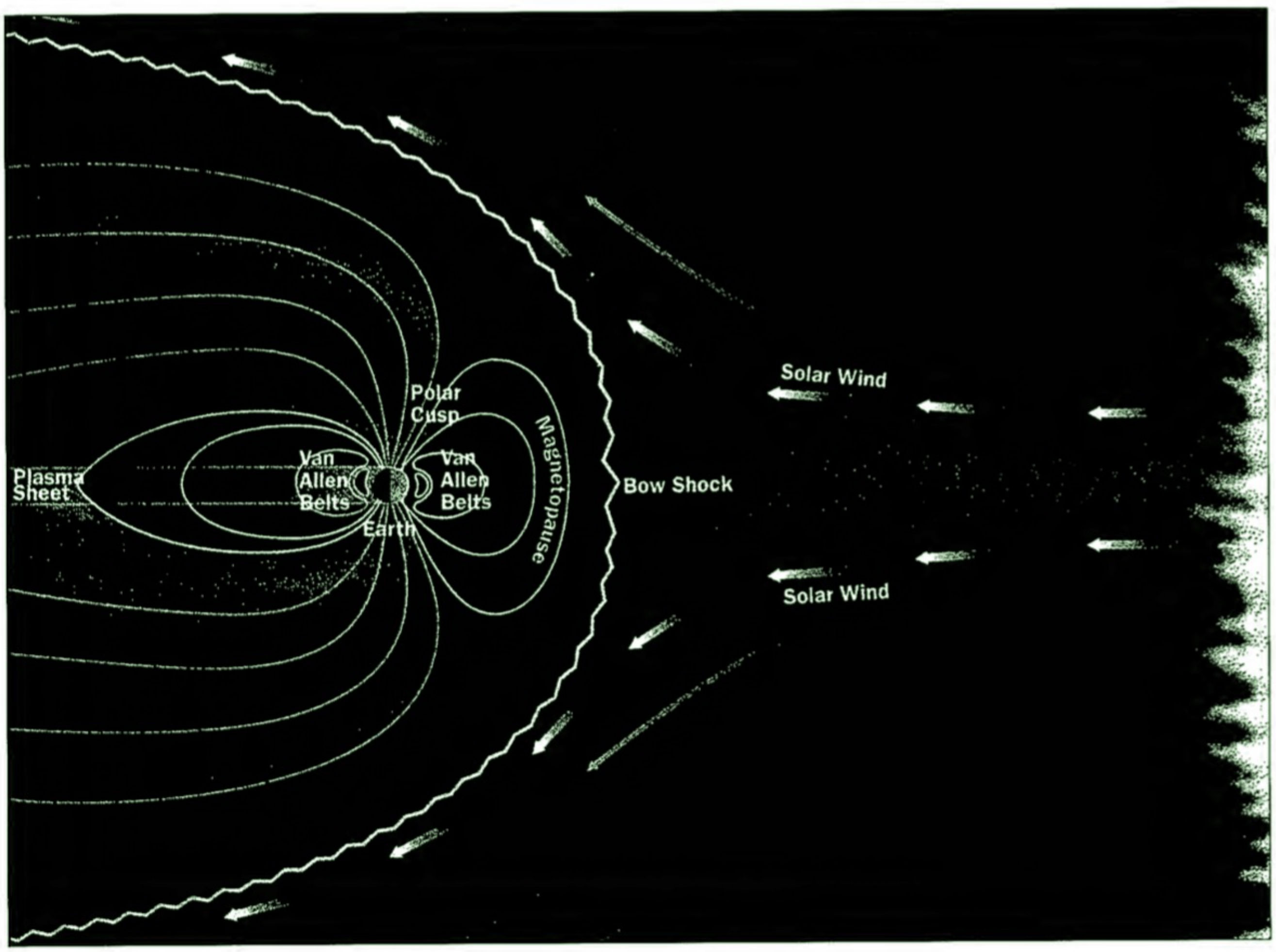

At high latitudes electron (and proton) with solar wind origin creates additional ionization, seen as aurora borealis/australis dispays

Above is from an EISCAT 3D presentation.

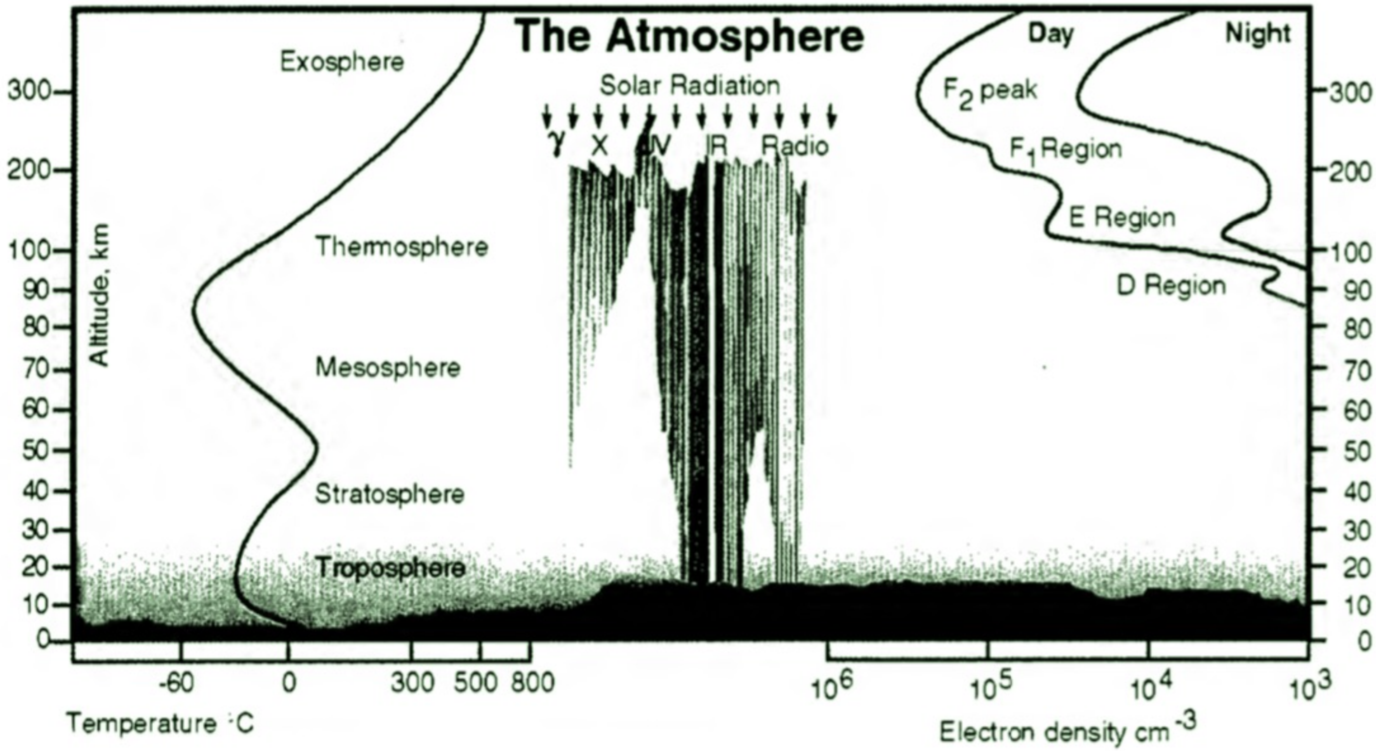
Pages below in black-and-white are from an HAARP presentation.

## GEOSPACE GLOBAL CHANGE

The Sun controls and shapes the three major regions of Geospace—the magnetosphere, the ionosphere, and the atmosphere. These regions, rather than being isolated, interact with each other and form a chain that connects the Earth to the Sun through the atmosphere and the solar terrestrial environment. Disturbances originating at the Sun spread through this chain via the solar wind and solar radiation. They ultimately influence our weather, our climate, and even our communications. The clouds and the Earth's surface play a critical role in this chain, which is finely tuned to be in a delicate equilibrium with life on Earth. The atmosphere and the ionosphere are the geospace

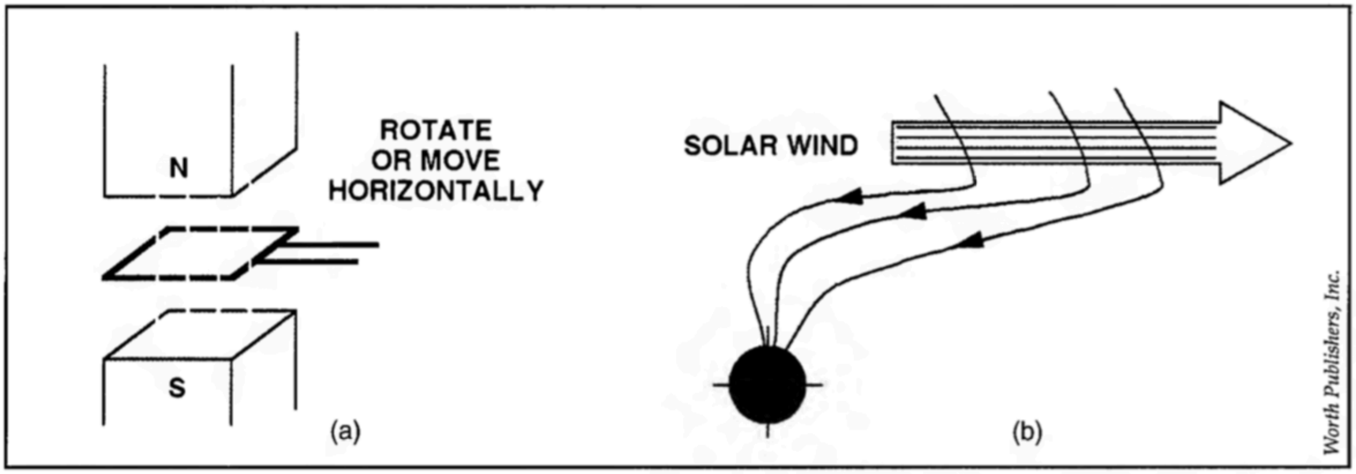



*The impact of the solar wind on the Earth's magnetosphere. The solar wind confines the Earth's magnetic field to a comet-shaped zone that has our planet as its nucleus. The magnetosphere is drawn out into a very long tail (not shown) that stretches away from the Sun.*



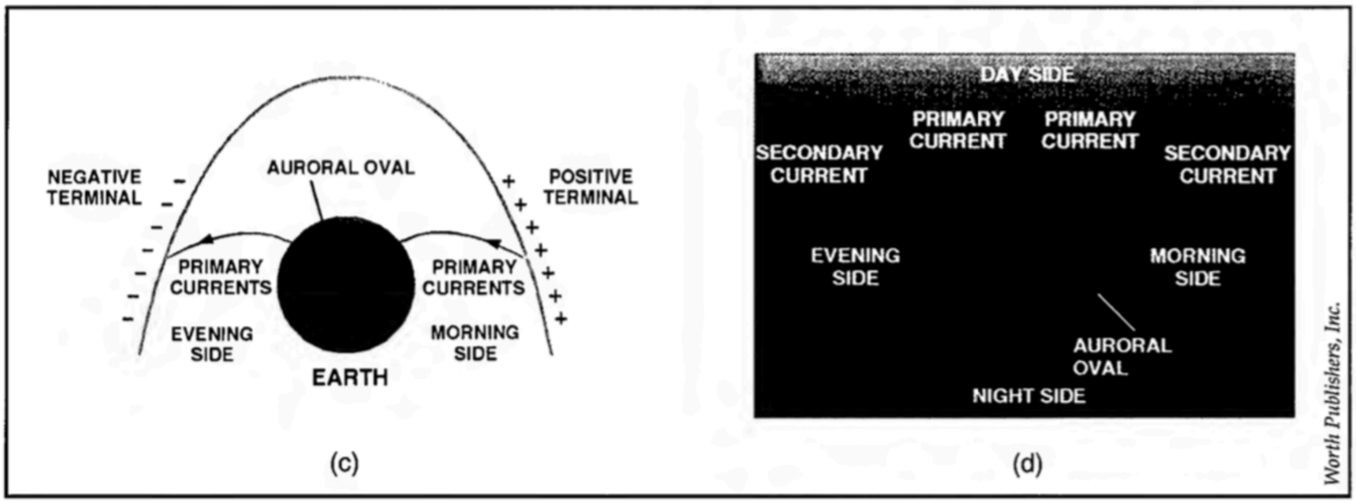

*Schematic representation of the atmosphere and the ionosphere. The altitude dependence of the temperature and electron density are shown on the left and right sides, respectively. The spectrum of solar radiation and its atmospheric absorption are shown in the middle. The ionosphere starts at about 70 km. Communication paths between the ground and satellites have to cross the ionosphere and the atmosphere.*

regions closest to the surface of the Earth. The lowest regions of the neutral atmosphere—the troposphere, the stratosphere, and the mesosphere—are critical in controlling the global temperature of the Earth and in filtering the harmful effects of the solar radiation. The next layer—the ionosphere—starts at about 60 – 70 km altitude and contains a significant fraction of electrically charged particles. Because charged particles are subjected to electric and magnetic forces, the ionosphere has a uniquely important role within the overall solar-terrestrial system. It couples to the magnetosphere and heliosphere above by electric forces and to the stratosphere below by conventional atmospheric dynamic forces. It is a region that supports and controls electric currents and potentials ranging up to a million amperes and hundreds of kilovolts, respectively.




*(a) Conventional generator*

*(b) The interaction of the solar wind with the Earth's magnetic field creates a naturally occurring generator.*




*(c) The positive and negative terminals of the naturally occurring generator are shown together with the primary currents.*

*(d) The primary currents induce secondary upward currents in the outer edge of the auroral oval to close the electrical discharge circuits. The currents across the polar cap and along the auroral oval depend on the atmosphere's conductivity.*

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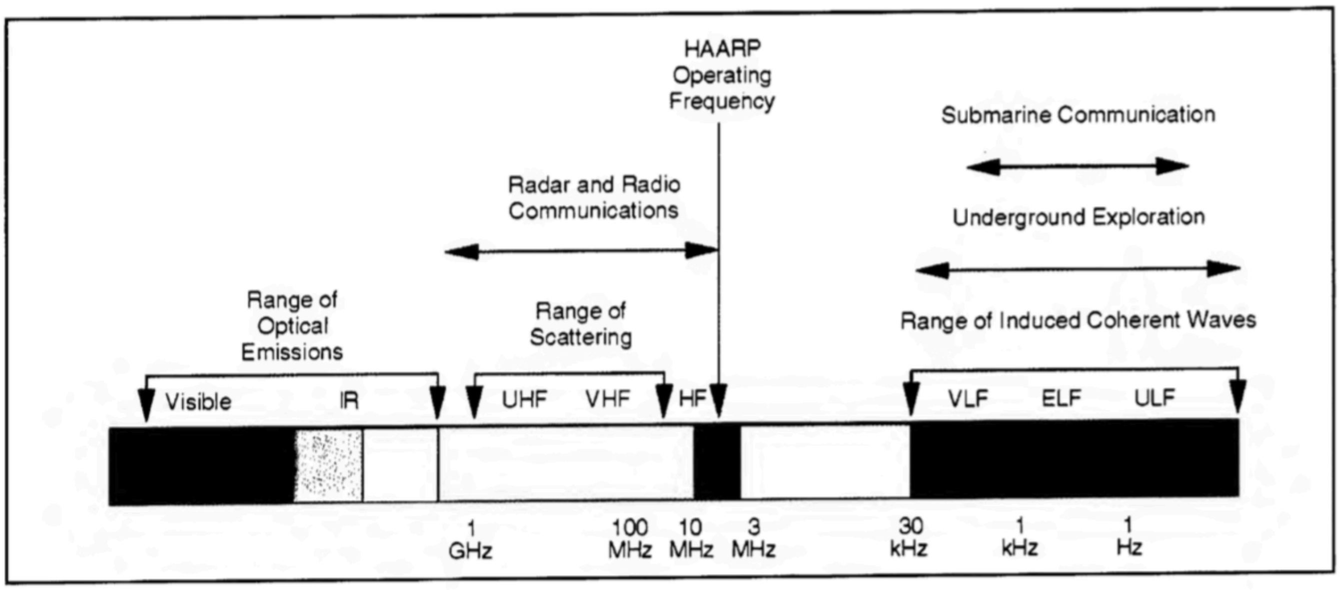
The polar ionosphere located above the Arctic is of particular significance. The magnetic field lines traversing this region connect directly to the solar wind—a stream of charged particles flowing outward from the Sun toward the magnetosphere, permitting direct access of solar wind particles into the ionosphere. Furthermore, the solar wind, functioning as a conductor, creates an electric generator. This is similar to the conventional generators that produce electric energy when a conductor moves or rotates across a magnetic field. The currents generated by the solar wind flow toward the Earth guided by the magnetic field and close the electric circuit by traversing the polar ionosphere. This is known as the auroral electrodynamic circuit and carries towards the Earth 0.1 to 1 million MW of power, equivalent to 100 to 1000 large power plants. The energy is dissipated in the polar ionosphere and transferred to the mesosphere, driving complex photochemical and plasma-physical processes. A fraction of this energy appears as a spectacular light display, known as the aurora borealis.

Remote sensing of the Arctic and monitoring of the state of the polar ionosphere is a prerequisite in understanding and modeling the global Earth system—a major goal of the U.S. Global Change Research Program (GCRP). Furthermore, increased reliance on space-based electromagnetic systems requires not only monitoring of the global ionospheric state but also an examination of the impact that controlled local modifications in the vicinity of transionospheric paths can have on these systems. The possibility that system performance can be influenced by controlled local modifications, using ground-based HF transmitters, could affect the planning and economics of space systems.

The HF Active Auroral Research Program (HAARP) is based on a HF transmitter and a complement of diagnostics located in Gakona, Alaska. The location of the HF transmitter underneath the auroral electrodynamic circuit and the power and flexibility of operation, based on use of today's most sophisticated technology, provide the HAARP with a novel and unique broadband remote sensing resource. By exploiting the properties of the auroral ionosphere as an active, nonlinear medium, the primary energy of the HF transmitter, which is confined in the frequency range from 2.8 to 10 MHz, can be down-converted in frequency to coherent low frequency waves spanning five decades, as well as up-converted to infrared and visible photons. It can, furthermore, structure the ionospheric density in a way that provides a controlled scatterer for HF/VHF/UHF frequencies. As a result, the HAARP HF transmitter can generate sources for remote sensing and communications spanning 16 decades in frequency.

This report describes and documents the importance of the HAARP in fulfilling the above requirements, in addition to advancing the scientific frontiers in ionospheric physics.




*The HAARP transmitter radiates in a narrow frequency range of 2.8 to 10 MHz. However, using the ionosphere as an active medium, it can provide secondary radiation sources in the IR, visible, and ULF/ELF/VLF ranges. It can also develop new links in the HF/VHF/UHF ranges by rippling the electron density of the ionosphere, thereby producing controlled scatterers at these frequencies.*

## HAARP Unique Features—Current Plan

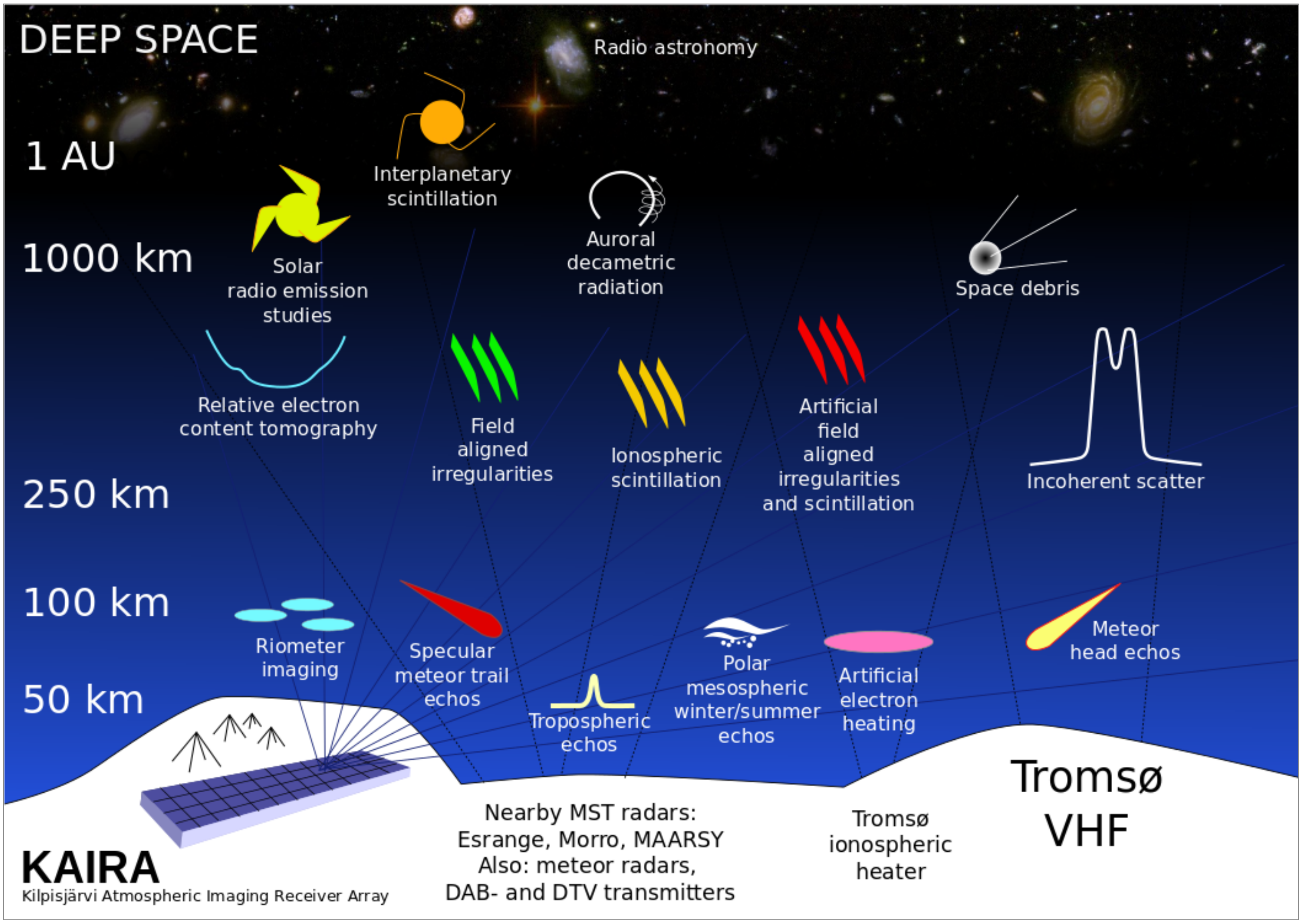
- 12x15 cross dipole array driven by 360 10 kW transmitters
- Very high effective radiated power: 86 to 96 dBW (2.8 to 10 MHz)
- Wide range of parametric control
  - Wide array operating band: 2.8 to 10 MHz (~two octaves)
  - Very wide scan: ±30° cone
  - Rapid beam scan: 10 μs
  - Arbitrary polarization: any cross or linear polarization
  - Beam shaping and radiation pattern control
- Modern fiber-optic control system
  - High-speed phase control (144 MB/s)
  - High-speed data communication
- Fast system computation: 1.28 GFLOPS
- Unique transportable and remotely operable graphic interface
- Integrated diagnostic support for control/coordination/expansion

## HAARP Diagnostic Instrumentation

| HAARP ACQUISITIONS | DIAGNOSTICS AVAILABLE TO HAARP |
|---|---|
| Magnetometer | University of Alaska, Geophysical Institute |
| ELF/VLF receivers | Magnetometer chain |
| Longwave wideband radiometer | Riometer chain |
| D region remote sensing receivers | Optical imager chain |
| HF vertical ionosounders | High latitude monitoring site (UA, Geophysical Institute) |
| HF stimulated EM emissions receiver | VHF (50 MHz) radar |
| HF (28 MHz) radar | Riometer |
| VHF (30 MHz) riometer | Magnetometer |
| VHF imaging riometer | Air weather service |
| VHF (50 MHz) radar | HF vertical ionosounder (College Station) |
| VHF (250 MHz) scintillation monitor | |
| UHF incoherent scatter radar* | |
| RF spectrum monitor | |
| Imaging photometer | **DIAGNOSTICS UNDER CONSIDERATION** |
| SWIR photometer | |
| SWIR imager | Satellite-based diagnostics |
| Rayleigh/ozone lidar | |
| Sodium resonance lidar | |

* Planned

KAIRA is part of EISCAT 3D (see above) and "LOFAR" (google it). Below from: http://kaira.sgo.fi/p/radars.html `



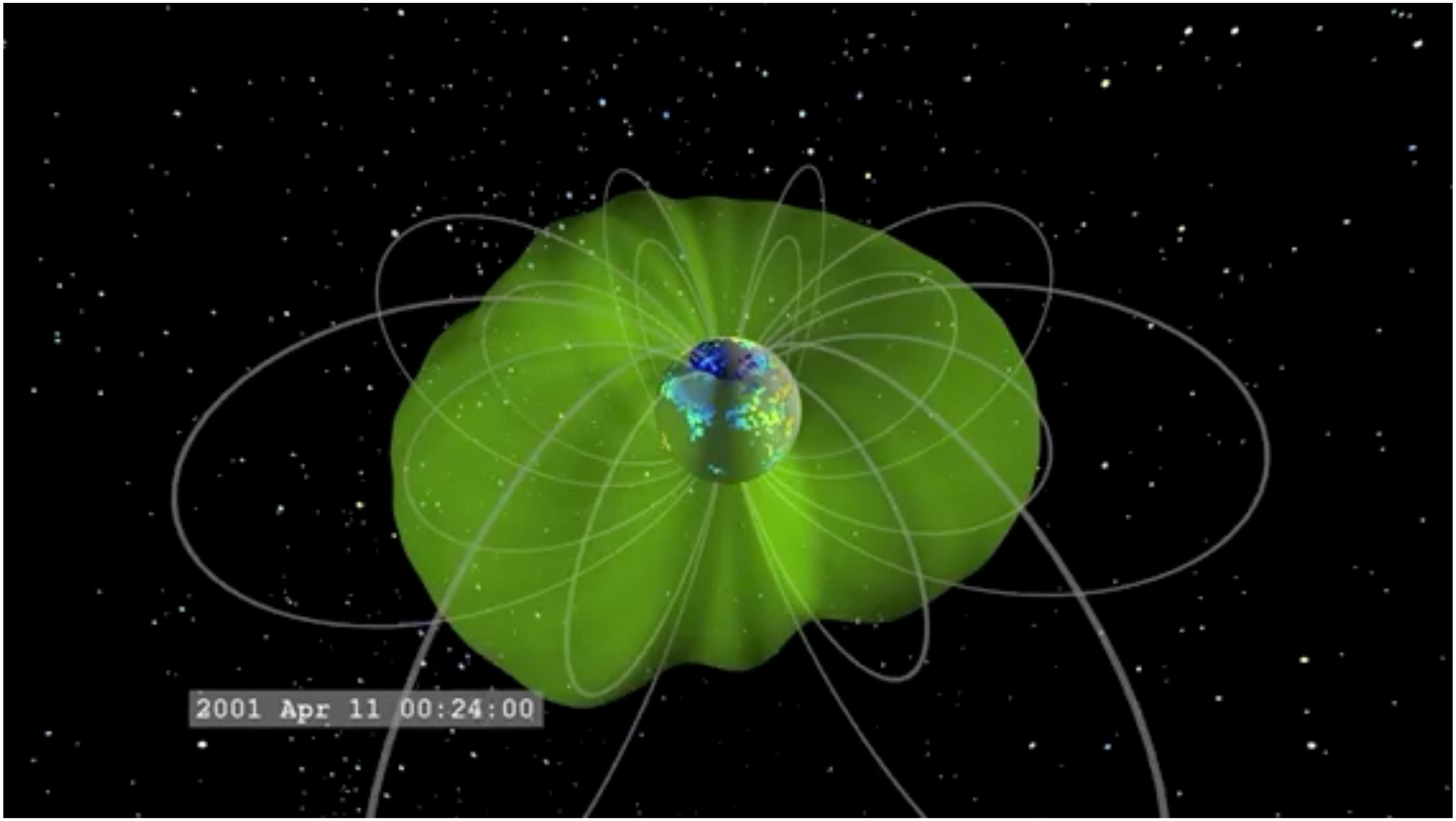

Above (with some background knowledge) generally depicts aspects of the following. Cost-effective globally distributed coordinated phased antenna arrays, some transmit and some receive and some both (most in HF, VHF, and lower UHF frequency ranges), will allow greatly expanded understanding, and beneficial control and use of earth's layers of atmospheres, which interact with "space weather" (from sun activity and some deeper space). This is a fundamental development of great significant to civilization not well known and thus far not well integrated and pursued. It is involves but should mainly be a science projects.

# EXHIBIT - 2

# POLARIS GLOBAL

## Global Radio Internet, Energy, Science, and Earth Defense System

Earth Ionosphere, Plasmasphere, and Magnetosphere - Individually Powered




CLICK https://svs.gsfc.nasa.gov/vis/a000000/a003300/a003312/a003312_H264_640x480_nodates.mp4

NASA

# POLARIS GLOBAL 3D

3D- use of Earth’s ionosphere-plasmasphere-magnetosphere (3D IPM)

- Radio systems: Perpetual ionosphere-plasmasphere sources support global high capacity communications (new internet); precise position, location and timing (pPNT) systems; pPNT beam 5G wireless enhancements; 3D skywave 5G; high capacity wireless to even more remote regions: enhanced by below.
- Energy systems: Ionosphere-plasmasphere and the coupled Magnetosphere support high capacity electric energy systems, direct to the users.
- Distributed super computing systems: People -built and -powered distributed evergreen super computing.
- Earth science systems: By above and by distributed radio transmit-receiver arrays providing advanced telescope instruments for investigation of IPM, coupled with other radio-telescope multistatic-sky-radar systems.
- Earth defense systems: Global warming mitigation; weather prediction improvements; disaster-weather mitigation; seismic, earthquake, volcano, and tsunami monitoring and prediction improvements; solar mass coronal ejection defense; and potentially distributed high-gain laser asteroid deflection defense.

POLARIS GLOBAL 3D

3D- use of Earth's ionosphere-plasmasphere-magnetosphere (3D IPM)

Using radio frequency transceiver arrays with facilities similar to the radioastronomy LOFAR and SKA for both space and atmosphere science, RF systems (enhanced broadband meteor burst centric), sub-nanosecond time synchronization and encryption, augmentation, via:

- Facilities 1: Phased arrays, mini-SKAs, timed for dual earth/ astronomy radio functions. Terrestrial and high seas.
- Facilities 2: Extensive private-facility rooftop stations combining solar-energy panels and RF transceivers.
- F2 distribution: Any stores, utilities, nonprofits, 'amazon's.
- Tech: ~ Eastlund US2007 patent 0238252A1(method and apparatus for altering a region in the earth's atmosphere, ionosphere, and/or magnetosphere). / A. Streltsov: Energy from Space Plasma; and Whistler waves' to protect communications from nuclear blast. / https://laserearthshield.info. / Plasma and rf-laser transducer antennas. In personal & IOT devices. / And see other slides and materials at this Polaris PNT website.

## Advanced Meteor Burst / Skywave Radio Systems

Billions of small meteoroids enter the atmosphere daily, few large enough to be visible, and create no-cost, ever-renewed, smart, plasma antenna arrays in the sky, responsive to 25-55 MHz.

This can be extended to ~1 GHz by relatively low-power RF (or laser+RF) heating of the billions of daily meteor plasma trails, enhancing their intensity and duration, without interference with terrestrial wireless: ‘5G’ skywave communications.

New radio, antenna and computer techniques will enable ‘5G’ skywave meteor burst radio and other skywave radio systems that are robust, secure, global with no coverage gaps, at low-cost-of-coverage.

It will deliver n-RTK for precision GPS-GNSS worldwide. It will also provide PNT (Position, Navigation and Timing) services independent of GNSS, and will be far more secure from sky or terrestrial attacks. It will improve atmospheric and weather science that is much needed, and provide other major benefits.

Reception of the many key data services will be via one-way broadcast, receivable in any radio device, even consumer smart phones.


http://www.oceanlight.com/log/category/new-work | light@yosemite.earth

# POLARIS GLOBAL 3D

The following slides are taken from materials on ‘2G’ current-generation meteor burst communications (MBC) systems made for very wide area robust but low-capacity systems mostly for remote-regions environmental telemetry.

While POLARIS GLOBAL plans ‘5G’ meteor burst communications and other skywave systems, the following is useful to show the fundamentals of meteor bust communications.  It is well established, easy to deploy and maintain, and robust.

The planned 5G MBC+ network facilities will provide the foundation for the other systems and services described above.

This is a slide below, also included here at the start to show that Meteor Burst Radio Signaling is well established as to *basic* principles and technology.

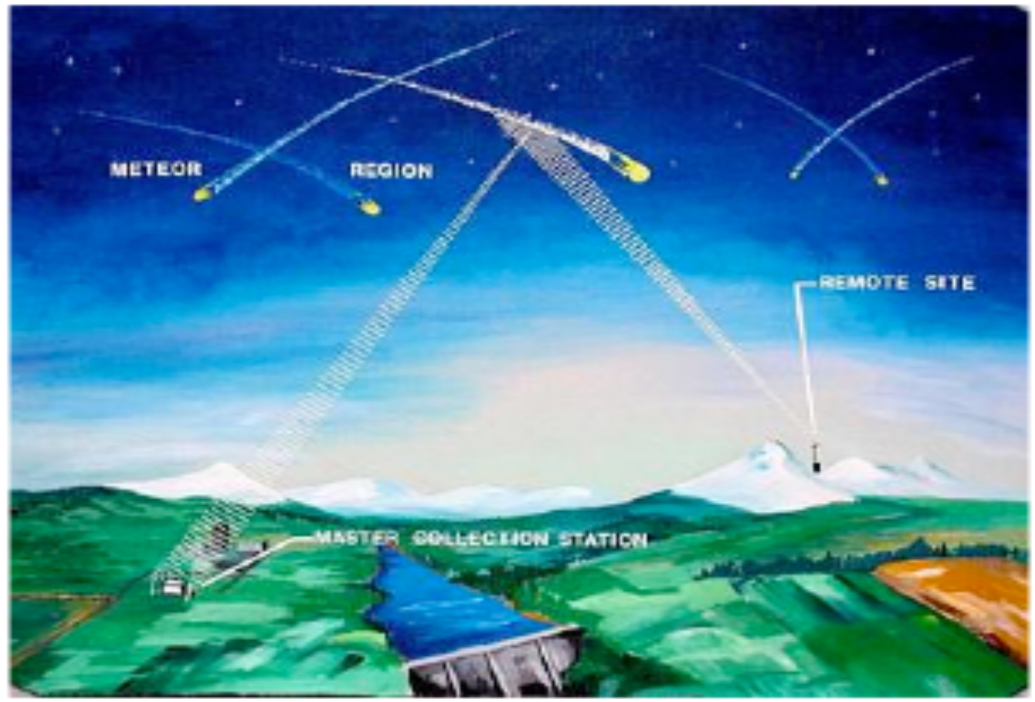
United States Department of Agriculture
NRCS Natural Resources Conservation Service
National Water and Climate Center

The National Water and Climate Center (NWCC) has developed efficient and highly effective technology to provide the data needed for water supply, climate, analysis, and conservation planning. NWCC acquires additional data sets that are needed from other networks and designs local data networks and sophisticated national networks. NWCC operates a variety of networks that use different data acquisition technology. We offer our expertise to others through documentation, training, partnership, on-site assistance, and participation in professional forums. Briefly, some of the types of data acquisition technology that are currently established are:

NRCS SNOTEL shows MBRS is successful for NCRS's critical purpose. Advanced MBRS discussed herein may, under on plan, complement SNOTEL in a 'partnership' – see left.

## Meteor Burst Communication Technology

Meteor burst communication was discovered by the military in the 1950's. NRCS implemented this technology and developed SNOTEL in 1975. Meteor burst communication uses the billions of sand sized particles (1 gram or larger) that burn up in the 50 to 80 mile high region of the atmosphere to relay radio signals back to the earth. This technique allows communication to take place between remote sites and a master station up to 1200 miles away. At the master station, the remote site data is checked for completeness. If so, an acknowledgment message, returning over the same path, tells the remote site not to transmit again during this polling period. The entire process takes place in less than a tenth of a second. Meteor burst communication has proven to be extremely reliable. From the master stations, the data are sent via telephone line to the NWCC Central Computer Facility.

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http://www.wcc.nrcs.usda.gov/publications/Briefing-Book/bb25.html

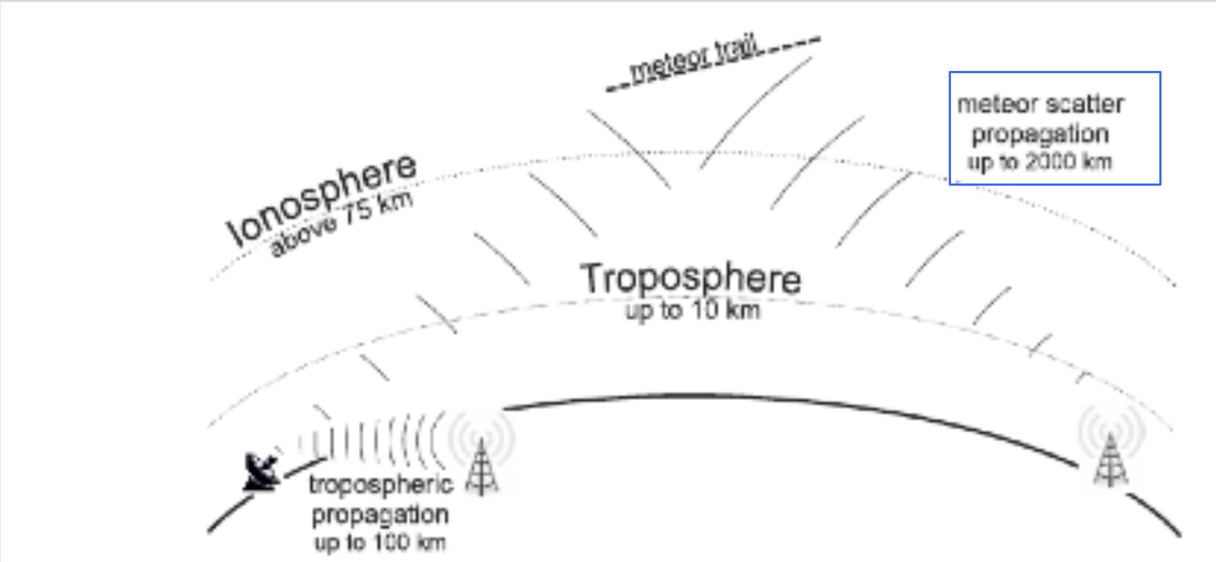


Fig. 1.— The principle of meteor scatter phenomenon.

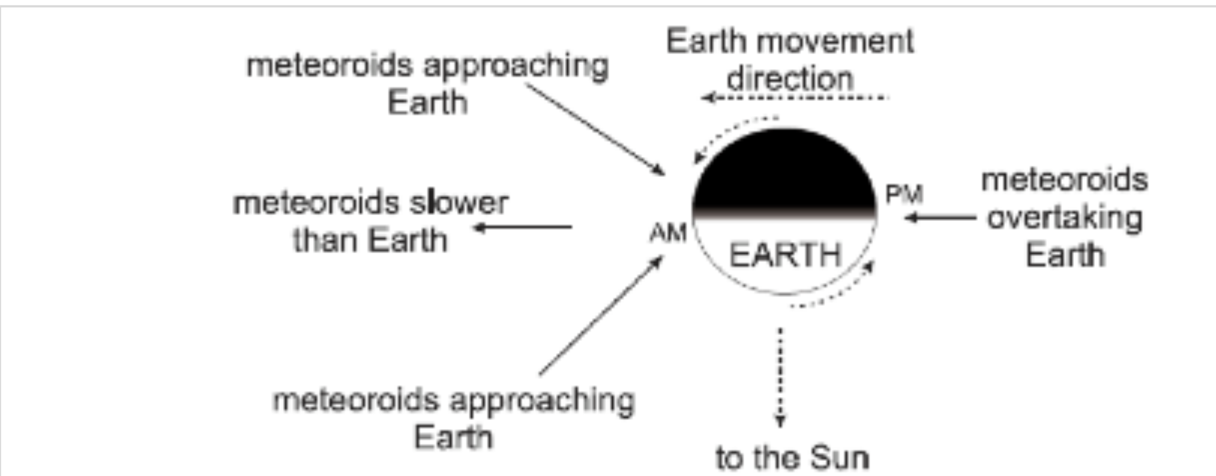


Fig. 2.— The visualization of the Earth in meteoroids environment.

Copy at: http://arxiv.org/pdf/1505.02366.pdf / Other depictions of MBRS elements provided below.

Note: The most complete work on "traditional" MBRS is:

Meteor Burst Communications: Theory and Practice, Donald L Schilling, editor. Wiley, 1993. See following pages.

Traditional MBRS is all that can be found in coherent form in public records, even current papers.* I have found indications of "advanced" MBRS in development in China and Russia, but the details do not appear to be publicized, and the authors and institutions do not respond to my inquires. In any case, I believe I have a more full and effective approach outlined herein.

The advanced MBRS outlined herein probably exceeds 1,000-fold in total performance and value as compared to "traditional" or modestly augmented MBRS found in most all papers on MBRS.

This is supported by assumptions using best-available MBRS system parameter data and what-if calculations.

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* E.g. http://www.ijetie.org/articles/IJETIE_201518006.pdf

## Meteors

What are they – where do they come from?
There are two main sources of small particle debris that constitute meteoroids….asteroids and comets…. Figure 2.1.

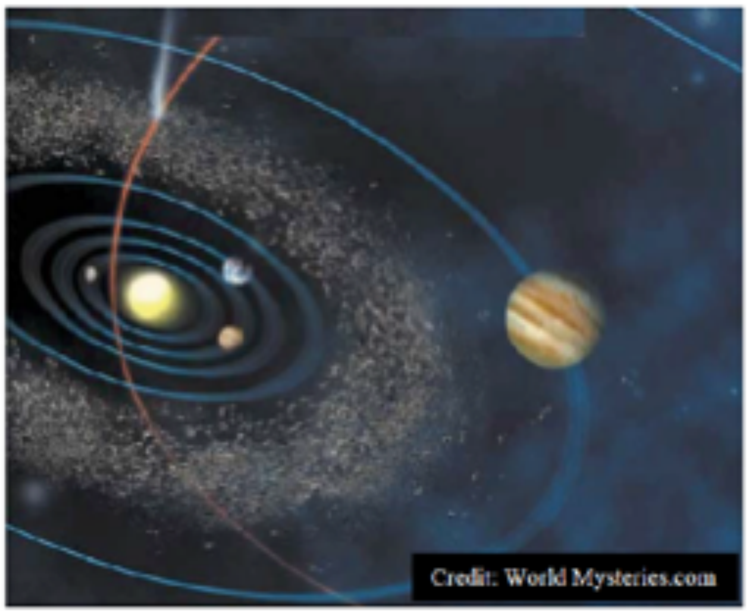


Figure 2.1
Comets and Asteroids as the source of Meteoroids

## Meteor trails

Meteor trails are formed when tiny particles, maybe the size of a grain of sand or smaller (see Figure 2.3) impact the Earth's upper atmosphere at a height of around 90km and generate a

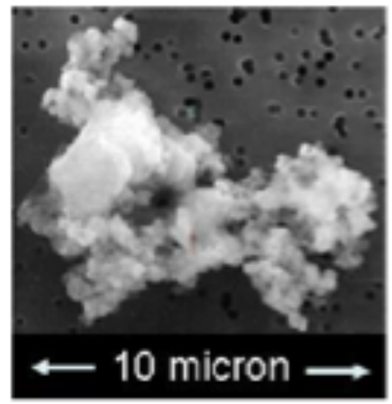


Figure 2.3
Example of a Meteoroid Particle

strong shock wave in the air. There is a huge temperature differential generated across the shock boundary and the radiant heat vaporizes the surface of the particle. This causes the ablation of the particle and ionization of the atoms of the material….

The vaporized material and ionized air play a large part in reflecting electromagnetic waves at radio frequencies – thus enabling their detection by VHF radar.

Here we examine the way the incident radar wave interacts with the ionized trail.  In Figure 3.3 we see the wave approaching a stream of ionized particles represented by a mix of positive ions, negative electrons and neutral molecules. It is only the electrons that respond significantly to the electric field in the incident wave.  The ions are heavy and do not move a significant amount and play little part in re-radiation of the pulse.  The neutral molecules carry no net charge and cannot interact with the wave electric field.  The strength of the returned signal is dependent on…electron density in the trail… this varies with time, so does the signal strength.

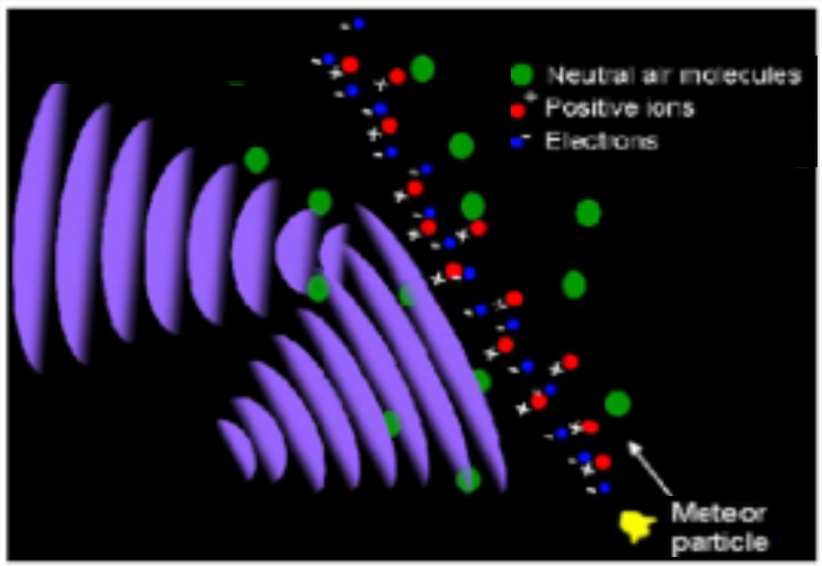


Figure 3.3   Wave interaction with the Ionization Trail

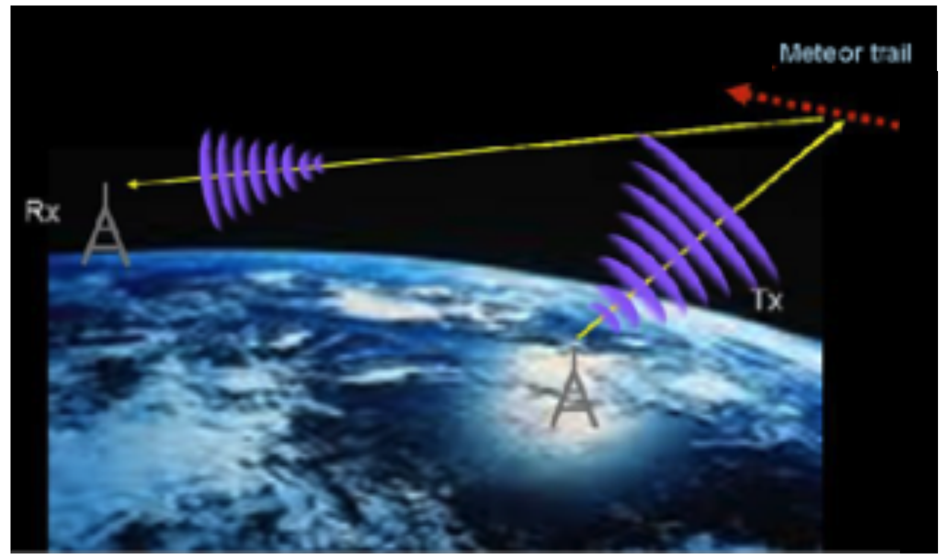


Figure 4.4   Reflection from a meteor trail

*Meteor Scatter* communication systems are highly efficient in its use of the radio spectrum. Radio frequencies are a scarce commodity and the increasing appetite for information demands economical use of the radio spectrum. Because in a large service area different users are "served" by different meteors, interference between the users is virtually ruled out, even if the same frequency is used over a very large area. In this way, the whole of Europe can be served by using only one or two channels, dependent upon the configuration of the communication network.

Note: The advanced MBRS outlined herein probably exceeds 1,000-fold in performance and value as compared to "traditional" or modestly augmented MBRS found in most all papers on MBRS, including the most advanced MBRS described in this 1993 book.


Meteor Burst Communications:
Theory and Practice
Donald L Schilling, editor. Wiley, 1993

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Part 1 below is from Mr. Shilling's oral history

Part 2 below has experts from the book

Part 1 From: http://ethw.org/Oral-History:Donald_Schilling

I co-authored 12 texts and more than 200 papers. I advised more than 75 Ph.D. students, many of who wrote their Ph.D. dissertations on CDMA related topics. In the 1960's I was involved with adaptive delta modulation, a voice digitization technique which was used by the military at that time; it is still used to perform analog to digital conversions…. I did the work initially for NASA, then after NASA I did it for the Army, and then for several other government agencies.

After the adaptive delta modulator I became involved in meteor burst communications, which was a wireless system used to transmit signals beyond the line of sight, using the meteor channel. Meteors are formed all the time, and we bounced our waves off of the meteors. If you do it right, you can get continual voice. A lot of this was done for the Air Force in Anchorage, where they transmitted between Anchorage and Kozebue, which is a city in Alaska right off the Russian border across the Bering Sea. It was a lookout station, and there was no real ionosphere to communicate back and forth, so they communicated off the meteors. We built the equipment and demonstrated that continual voice could actually be achieved if it was done properly. We had an adaptive system.

I edited a textbook for … Wiley on Meteor Burst Communications, which dealt with that whole area.

Part 2

....Today, we know that to be true because man has walked on the moon, space travel has become… common…, high-energy lasers are used in the medical…and other areas, communication satellites carry voice and data circuits to all points of the globe, and there is meteor burst technology. Meteor burst technology? ["MB"] What's this? Are we bursting meteors? No, just another communications medium…until the early 1970s…virtually ignored.

Discovered in 1935 by a gentleman named Skellet, the technology was considered antediluvian in face of the then current communication systems.... Skellet found that when a meteor entered the earth's atmosphere, the denser air caused the meteor to heat up and eventually burn, creating an ionized trail. He discovered that the ionized trail could be used to bounce a radio signal back to earth. Scientists have known for decades that the earth is continually bombarded by meteors…. One hundred billion meteors have been estimated to enter or pass through the earth's atmosphere in a 24-hour period.

From the 1950s through the 1970s, meteor burst technology was studied and actual tests were conducted to determine the feasibility of using the meteor trails to an advantage. The result of that research produced some interesting information....

Ionized trails were found to have a lifetime of only a few tenths of a second, creating the need for rapid exchange of communication. The transmission rate had to be very fast (a burst of data if you will) to take advantage of the ionized trail. Hence the term "meteor burst" was coined. [U]ntil the availability of integrated solid-state micro-computers, meteor burst as a communication medium was not considered practical except for slow-speed data.... * * * * These short-lived… signals, or meteor bursts, may last from several milliseconds to many seconds.

Signal duration depends on trail line density, initial radius, diffusion rate, electron attachment and the state of upper atmospheric winds. Digital communications is possible during these brief, intermittent meteor bursts, thus forming the basis for an over-the-horizon digital radio link. Since persistent meteoric ionization useful for trail-scatter occurs between 80 and 120 km above the earth's surface, maximum propagation distances of 2400 km are possible. The maximum usable distance for communications, however, is generally below 2000 km because of earth blockage, terrain obstructions, and antenna pattern ground tuck. The time dependence of the trail-scattered RSL depends on the electron volume density in the meteor trail as well as atmospheric parameters.... * * * *

The Alaskan Air Command was the first to install a high-powered, 8kb voice-synthesized MB system as an operational commun-ication medium. Uniquely designed, it supports the operational requirements for Air Sovereignty in Alaska. Other uses may come to light that will parallel those of the Alaska Air Command. However, there will always be a need for inexpensive data systems within the military and in industry. Currently, NORAD is testing a C3 meteor burst network that will connect the Continental United States, Alaska and Canada.

The Alaska National Guard recently installed a MB system that ties the headquarters to remote locations throughout the state. Again, the cost of acquiring a MB system is considerably less than that of other systems, especially in the Alaskan environment. Other countries are now looking into the benefits of a MB system for specific applications, applications where great distances are involved and civil engineering support is too costly for other remote systems. A MB system has been installed between Sondres- trom AB and Thule AB, Greenland. The north-south link operates be- tween 45 and 104MHz. The system is a test bed to investigate performance during polar cap absorption (PCA) events.
…Popular Mechanics that described a MB system for truckers….

In the tactical arena, small portable transceivers could be used by the military in a variety of applications such as resupply nets, status of forces nets, intelligence nets, and others. The Navy could make use of a MB unit that was released under water and brought to the surface by buoy. This application would enable communications while minimizing detection. An oil platform out in the middle of a sea is the ideal application for MB. Red Cross and Civil Defense organizations could use portable MB systems to provide logistic support during natural disasters such as earthquake, flood, and fire. Alarm systems, emergency or logistical networks, and similar systems could be provided in remote locations at a fraction of the cost of comparable systems. Anywhere there is a need for data, MB is an inexpensive alternative that warrants consideration. The applications are limitless and await only the imagination of the far-sighted.... * * * *

It is true that faster is better in terms of system processing times…. However, there are applications where "instant" is not part of the vocabulary. The Alaska SNOTEL net is a good example. Meteorological information is required on a regular basis; however, it is collected over a 24-h period. A slow data base update is acceptable and is tailored to the data collection requirement. The prerequisite for that system is that the data must get through in a timely manner.…

One only need analyze the basic information requirement, that is, life-cycle and time-to-live needs, to make decisions in choosing a baseline communications medium. Immediate update is not always the best answer to an equation…. In spite of the popular demand for more speed, systems like meteor burst still fill special application needs. Certainly, MB systems can be designed to perform as quickly as other systems through the use of new products now available in today's market.

In terms of cost, survivability, and intrusion resistance, meteor burst is hard to beat. Furthermore, it has that special Buck Rogers mystique… how else MB can be used.

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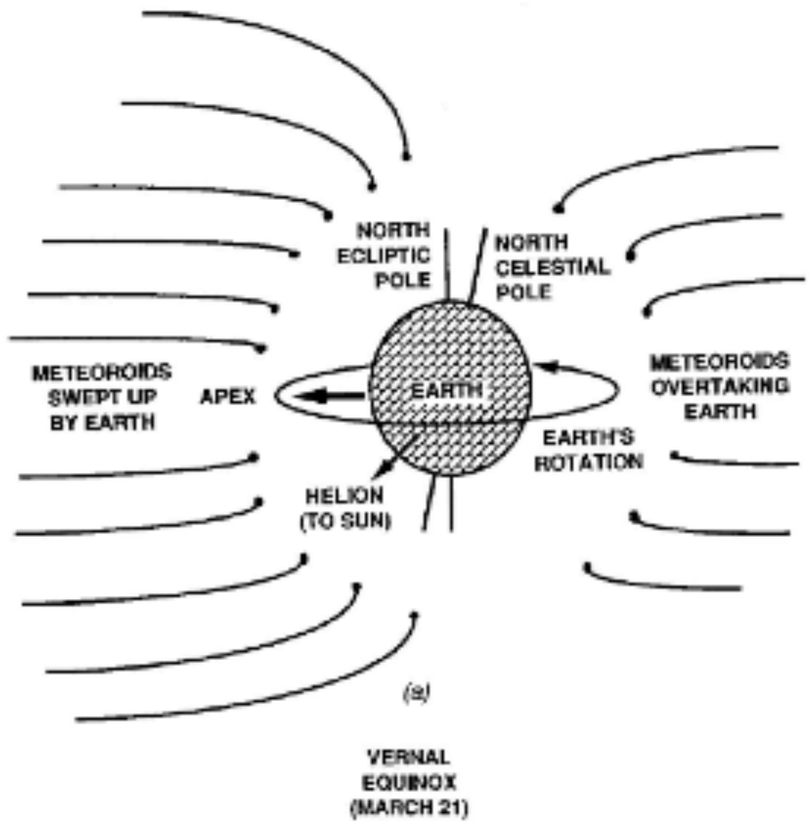
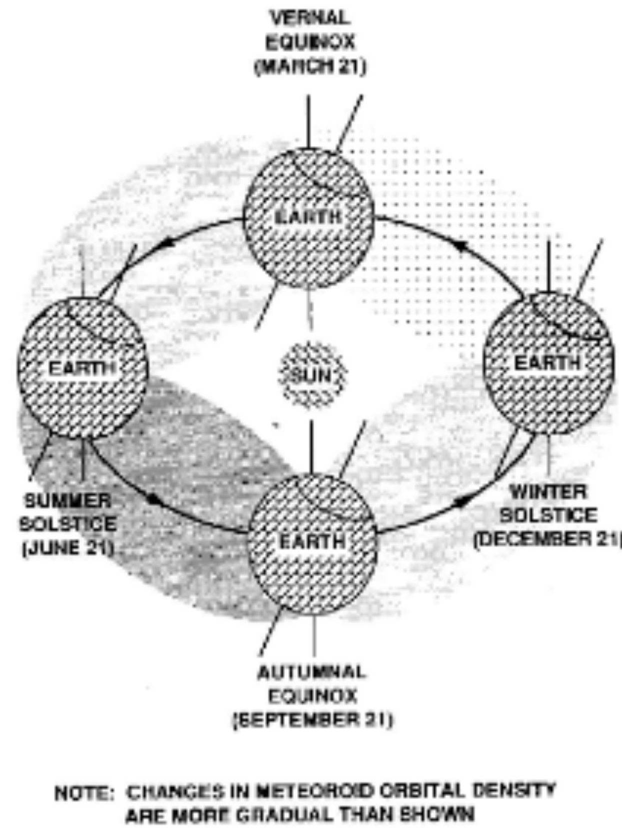
The following depictions are also (as are the introductory text excerpts above) from the book: Meteor Burst Communications: Theory and Practice . Donald L Schilling, editor. Wiley, 1993

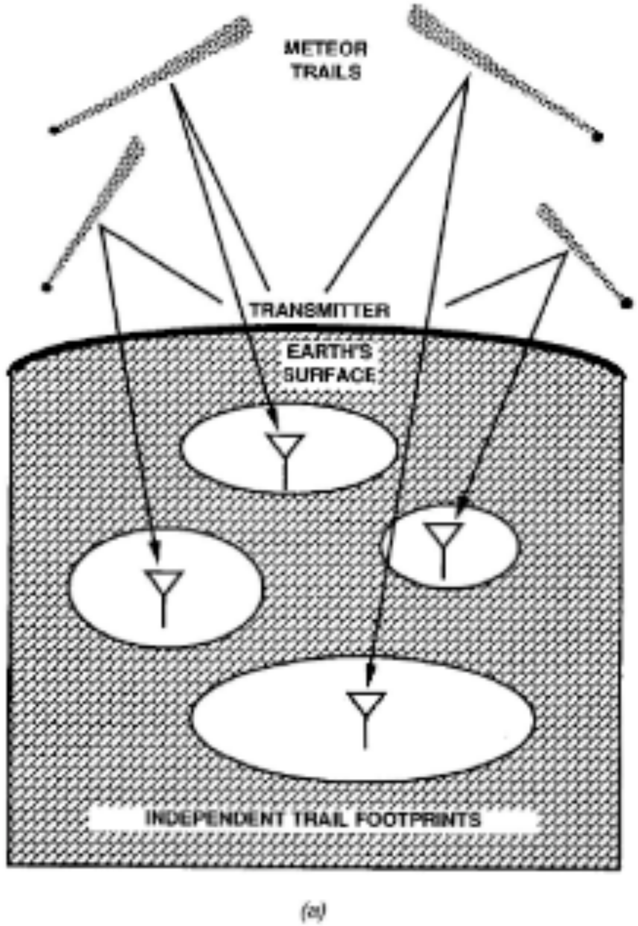
The advanced MBRS outlined in this PPT would have more advanced master base station and remote radios that are at issue in the text above and indicated by some of the drawings below.



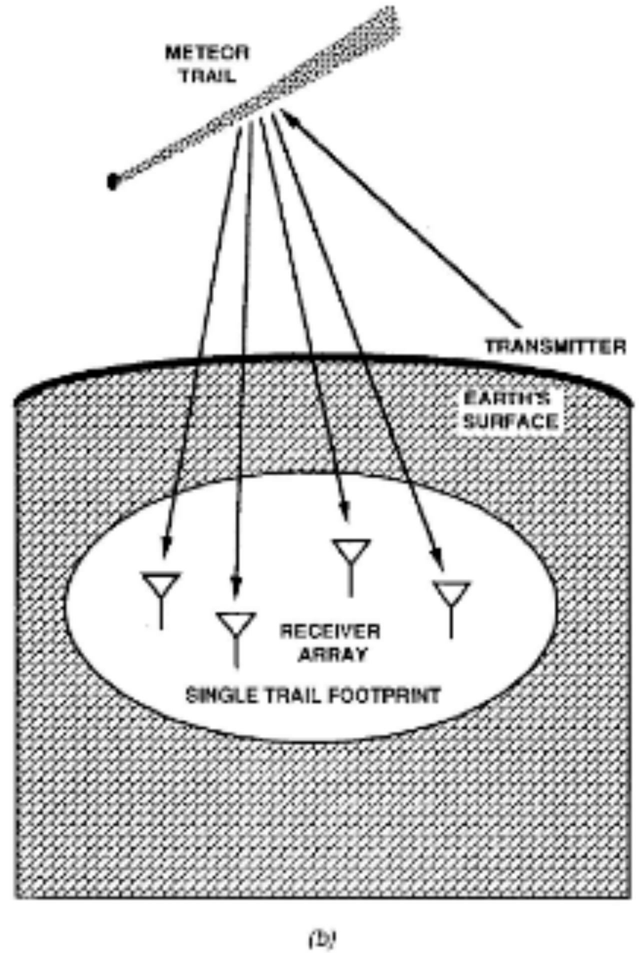

Diurnal variation in meteor rate




Seasonal variation in meteor rate




Spaced receivers in unique footprints




Closely spaced receivers in common footprint

Remote radio antennas is sufficiently close proximity can be linked and synchronized to improve signal to noise ratios, and to have more meteor-trail events (in '(a)' and longer time per event (in '(b)'). Each remote radio can also have phased receiver/ antennas, as explained on one slide herein from an engineer at the KAIRA radio facility.

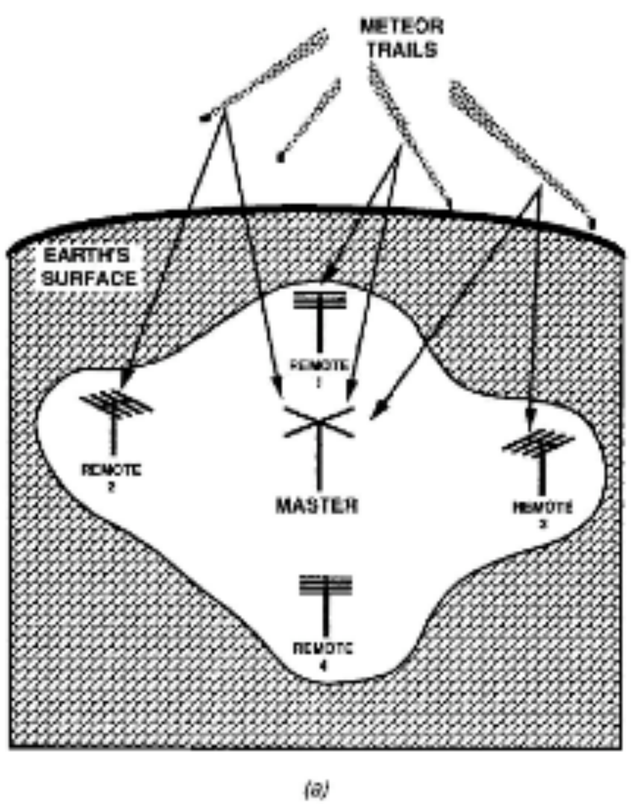



Figure 3.16 (a) Centrally-located master station

Typically, for a base station well inland to cover in all or many directions. With base station antenna arrays, the array could simultaneously cover in many directions.

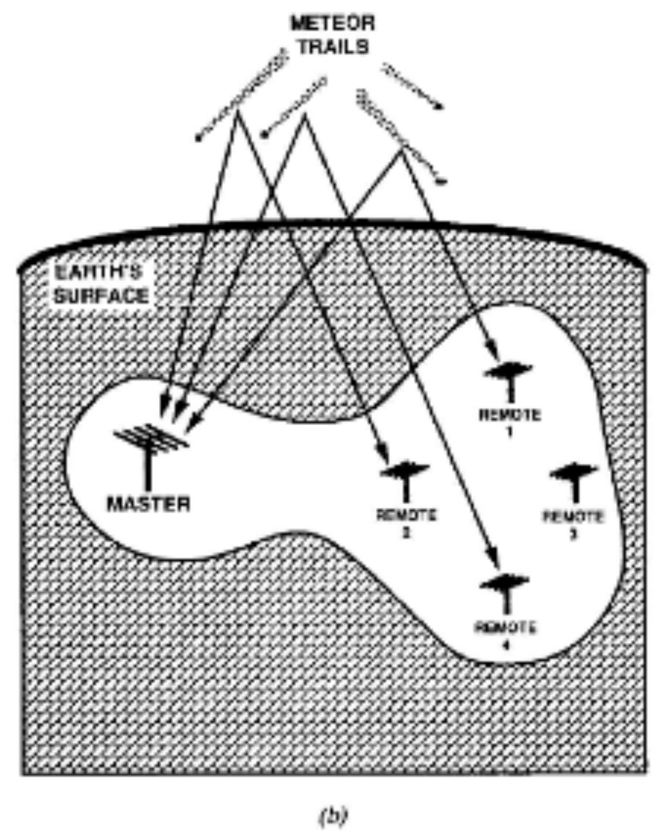
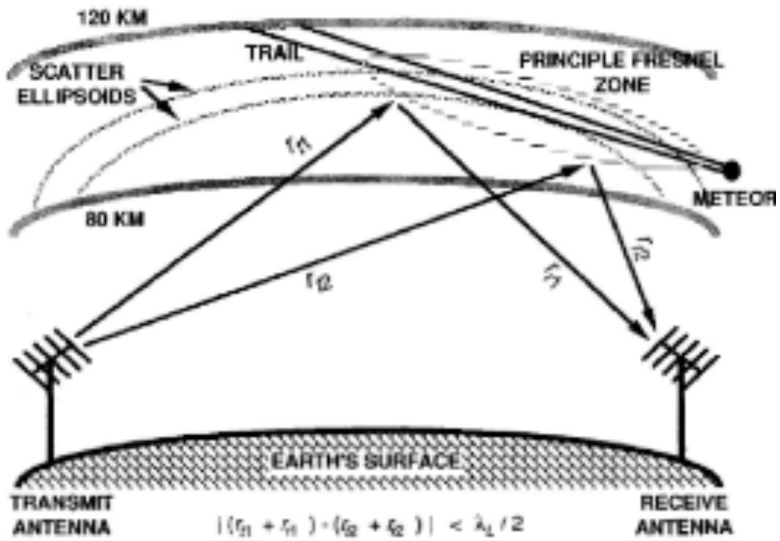
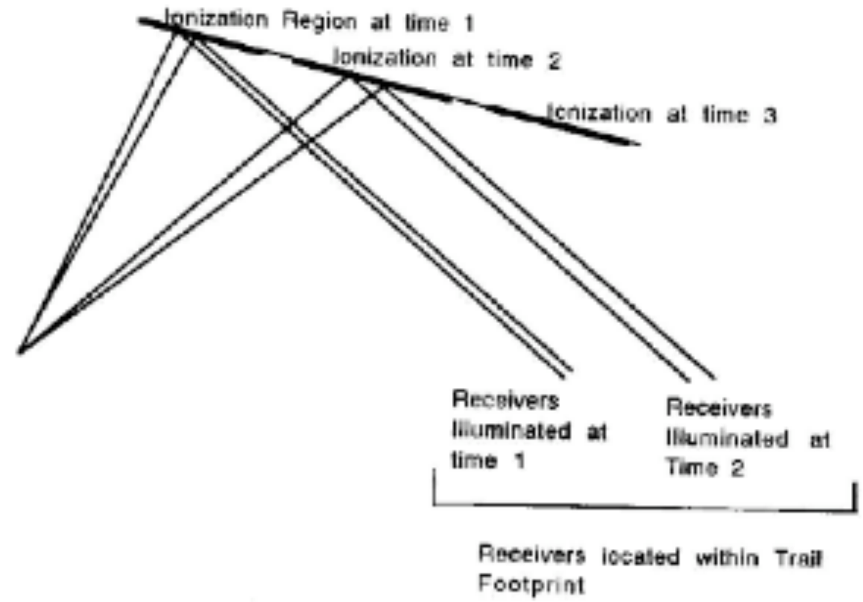



Figure 3.16 (b) Stand-off master station

Typically, for a base station on or near a coastline or other territorial border to cover offshore or beyond the border (with any permissions needed by another jurisdiction).




Link geometry for meteor trail-scatter




Motion of the ground illumination region
due to trail formation and decay

# EXHIBIT - 3

*Proprietary. v2.0* *

# Advanced Continental Low-VHF 20-55 MHz

## Meteor Burst Radio Signaling Networks

(MB) (MBRS)

and

## Low VHF Ground Wave Radio Signaling Networks

(lvGWRS)

For critical infrastructure & services, including:

MBRS: for broadcast data (for N-RTK for GPS/ GNSS high accuracy; other), 2-way comms, MB positioning navigation & timing (GPS independent) ("iPNT"), MB encryption, atmospheric science and prediction…

GWRS: for best, low interference and attenuation, LOS & NLOS networks in urban and indoor iPNT and low-rate networks for geolocation, ground drones, search & rescue, smart cities and buildings…

## Before the NTIA and US PNT Agencies

By Warren Havens, Berkeley CA. January 2016. * Copy and related at: polarispnt.space

Federal and other government entities hold substantial radio spectrum in the ranges suitable for MBRS. Advanced MBRS, as indicated herein, can provide highly cost effective and critical benefits to the nation.

Wireless pPNT – radio *signaling and data* for precise position, navigation and timing— is far more important than wireless *communications*. Advanced MBRS & ivGWRS can and should play a major role in nationwide pPNT.

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* Upon federal entity request, I may provide a confidential, expanded version of this presentation that expands material herein with information and ideas that are my trade secrets subject to patent actions.

## Advanced Meteor Burst Radio Signaling

Billions of small meteoroids enter the atmosphere daily, few large enough to be visible, and create no-cost, ever-renewed, smart, plasma antenna arrays in the sky, responsive to 25-55 MHz.

With new radio, antenna and computer techniques, this will enable ‘4G’ and ‘5G’ Meteor Burst Radio Signaling services that are robust, secure, continent wide with no coverage gaps, at low-cost-of-coverage.

It will deliver n-RTK for precision GPS nationwide. It will also provide Position, Navigation and Timing services independent of GPS and far more secure from sky or terrestrial attacks.  It will also improve atmospheric and weather science that is much needed, and provide other major benefits.

NTIA and FCC spectrum is available, and otherwise is little used.

Reception of the many key data services will be via one-way broadcast, receivable in any radio device, even consumer smart phones.


http://www.oceanlight.com/log/category/new-work | light@yosemite.earth

This is a slide below, also included here at the start to show that Meteor Burst Radio Signaling is well established as to *basic* principles and technology.

United States Department of Agriculture
NRCS Natural Resources Conservation Service
National Water and Climate Center

The National Water and Climate Center (NWCC) has developed efficient and highly effective technology to provide the data needed for water supply, climate, analysis, and conservation planning. NWCC acquires additional data sets that are needed from other networks and designs local data networks and sophisticated national networks. NWCC operates a variety of networks that use different data acquisition technology. We offer our expertise to others through documentation, training, partnership, on-site assistance, and participation in professional forums. Briefly, some of the types of data acquisition technology that are currently established are:

NRCS SNOTEL shows MBRS is successful for NCRS's critical purpose. Advanced MBRS discussed herein may, under on plan, complement SNOTEL in a 'partnership' – see left.

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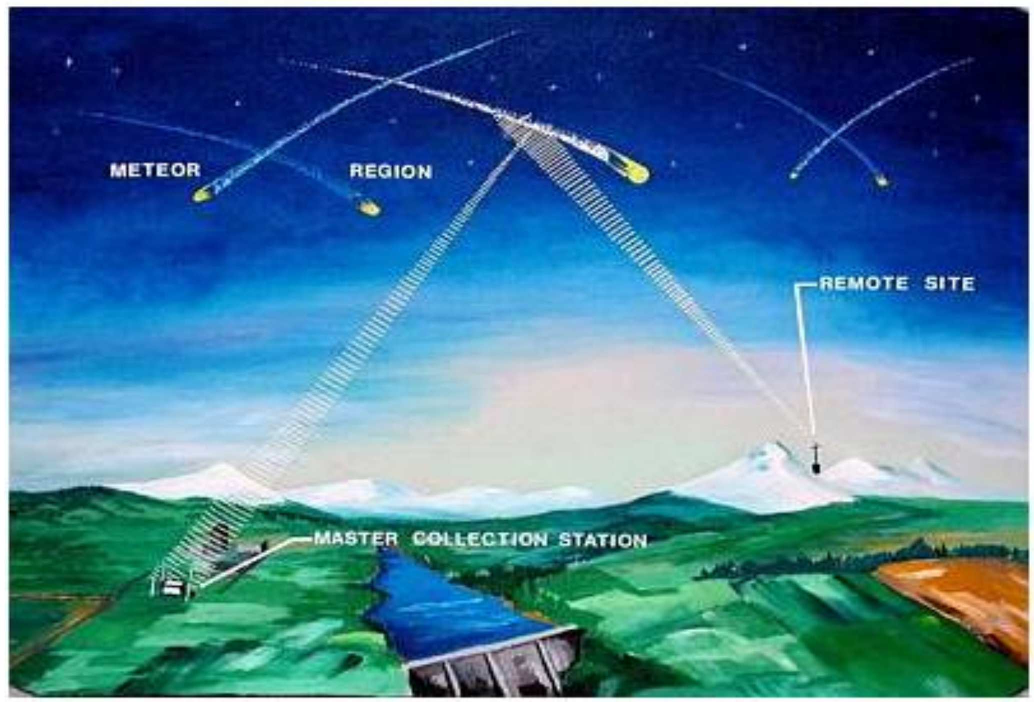



**Electronics Maintenance Facility**

The NWCC operates a SNOTEL electronics maintenance facility that maintains a fully functional complement of modular SNOTEL components that can be sent overnight, worldwide if a component fails. The facility also repairs data acquisition systems sent in from the field, designs custom interface boards, tests sensors, keeps abreast of latest technology, and provides answers to technical questions related to data acquisition technology.

http://www.wcc.nrcs.usda.gov/publications/Briefing-Book/bb25.html

# Low VHF Ground Wave Radio Signaling Networks

This is derived from slides below, included here as an introduction.

ARL

US Army Research Laboratory

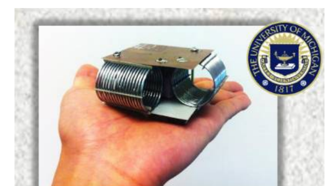
## Low VHF Channel Measurements and Simulations in Indoor and Outdoor Scenarios

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

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**



**Small Antennas for Low VHF Comms**

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

Section Contents & Narrative

I. Advanced MBRS – what and why

II. Advanced MBRS – how – technologies

In this v 1.0, some sections below combine a number of related outlined in this Contents list. The list provided a useful outline of topics covered in slides below.

See also -

POLARISPNT.SPACE

See footnote on the cover slide above, regarding confidential additions.

I. Advanced MBRS – what and why

1. Introduction, need and goals

2. Presentation context
- FCC and US have authority…

3. US PNT Agencies

4. What is MBRS, and Advanced MBRS
- US PNT (Position, Navigation & Timing) and Federal Radionavigation Plan
- US DOA NCRS example - SNOTEL - 700+ stations for environment monitoring
- Advanced MBRS and GPS are related
- DOA, NOAA, US GPS office (at DOC) should cooperate on MBRS including for ipPNT (GPS- independent precise Position, Navigation & Timing)

5. Why MBRS is unique and critical including for national security and productivity, by providing (see also 13 below)
- (i) GPS-independent pPNT (precise Position, Navigation & Timing) underlying smart infrastructure and services
- (ii) ubiquitous wireless far more robust and survivable than any terrestrial, satellite or landline wireless
- (iii) the base-communication-foundation for smart infrastructure, services, and environment monitoring and protection

6. US always has been and - *may* - remain leader in MBRS and GNSS
- This should be advanced, but if not pursued now seriously, Russia, China and others are advancing MBRS

7. Deployment of MBRS
- (a) NTIA-DOA-NOAA lead and preemption, (b) FCC cooperation, and (c) nonprofit "private commons"
- Federal and cooperative State and local government have dedicated MBRS (VPN and otherwise), and others have private commons (as FCC defines) access to create large demand and development (similar to DARPA model)

Section Contents (continued)

8. Spectrum availability (and no other spectrum users affected)
   - NTIA spectrum, FCC licensed spectrum, TV low-band 'white space' spectrum, and other for passive MBRS radar
   - Smart and cognitive basis - especially suitable in MBRS

9. Low VHF Noise reduction, and noise benefits
   - And why ~40 MHz (25-55 MHz) should primarily be for MBRS, augmented by terrestrial wireless in same and other ranges

10. Practical time now for Advanced MBRS
    - Convergence of needs, with advances in computer, radio, antenna, and other tech, and projections

11. Why ipPNT (GPS-independent precise Position, Navigation & Timing) is more important than radio communications
    - "Smart," secure, stable systems are based on precision of time and location (how the Universe works)
    - GPS and GNSS is not and cannot be sufficiently secure from space and terrestrial attacks – and needs a backup
    - MBRS ipPNT can be coordinated with NIST timing services, and any other GPS augmentation and backup

12. MBRS and nationwide drone wireless – mutually beneficial
    - FAA application:  MBRS delivery of nRTK to drones for precise movements, and height and 2d boundary policing.
    - MBRS can use drones with synchronized antennas for one- /and two- way MBRS signaling from/to master stations

13. Easy implementation in all 'smart' phones and other radio devices- vendors pay nominal costs

14. Early phase commencement using existing federal and TV stations – nominal costs
    - Second phase should and would not need them, but can continue to use for enhancement

15. Substantially applicable cost benefit studies- University of California Berkeley and others

16. Integration of Advanced MBRS and lvGWRS for Ubiquitous Continental+ ipPNT.
    - Same mobile transceivers, and the two solve urban and indoor RF NLOS inaccuracies and attenuation in higher bands

[Go to next page]

Section Contents (continued)

<u>II. Advanced MBRS – technologies</u>

1. Advances in MBRS in recent periods (after preceding "traditional" MBRS).
2. Integration of MBRS in 'smart' phones and other radio devices.
3. MBRS for ipPNT – GPS independent precise Position Navigation and Timing. In most all federal agency goals.
4. MBRS for pPNT via nRTK (network real time kinematic GPS/ GNSS). In many all federal agency goals.
5. China and Russian MBRS work (mostly kept non public)
6. SDR remote transceivers to match the base arrays, and the ipPNT functions
7. Radio Astronomy and Earth Atmosphere (radar) base station arrays and computing
8. SDR tech and products for multiple purposes (base, remote, relay, and other radios)
9. Bi- and multi-static MBRS radar and related
10. Passive MBRS radar (part of ipPNT) using TV and federal station stations
11. MBRS for GPS- or-better timing (fully independent of GPS/ GNSS)
12. MBRS for encryption (of any signal)- benefits over math-based encryption. In all Federal agency goals.
13. MBRS for earth atmosphere and weather prediction, as as foundation for possibly needed mitigating changes in Ionosphere to counter global warming. In DOA and NOAA goals, and indirectly other federal agencies.
14. MBRS in support of super wide area radio astronomy (adjacent frequencies). In NSF National Radio Astronomy Observatory goals.
15. Low VHF Ground Wave Radio Signaling Networks (lvGWRS) In US Army goals. Extensible to all federal and other government agencies.

In this v 1.0, some sections below combine a number of related outlined in this Contents list. The list provided a useful outline of topics covered in slides below.

See also -

*POLARISPNT.SPACE*

See footnote on the cover slide above, regarding confidential additions.

*Proprietary*

Introduction

Warren Havens, the author of this presentation explains:

I prepared the website : www.terranautx.com.   Hererin, I do *not* refer to any licensee or license in that website.

Herein, ~40 MHz" and "40 MHz" means 25-55 MHz +/-, the ideal range for MBRS.

The various aspects of MBRS, and most of the technologies herein, are not well known.  Explanations of the fundamentals and details of each are in extensive public sources, many found by "googling."  While I provide substantial explanations below, mostly in Part I, a better understanding of this presentation requires additional background knowledge.

MBRS can be used directly for pPNT (independent of GPS/ GNSS), and indirectly by delivering nRTK data and in other ways.

Wireless pPNT – radio *signaling and data* for precise position, navigation and timing-- *is far more important* than more wireless *communications*. E.g., see www.terranautx.com.   Also see www.polarisPNT.space.

For the needed ubiquitous nationwide pPNT, lowband VHF is needed.   Nonprofit public- private commons are needed as well.

For more capacity in high-use areas, other spectrum and networks would be used and integrated.

The following slides primarily give information on current advanced technology available as-is, or with reasonable adaptation given the scale involved.

Comments below in boxes are added for further explanation of the text and graphics, most of which are largely self explanatory in context of the slides above, including the p. 3 chart, for the suitably informed reader.

Most of the below are excerpts from the documents named.  Underlining is added.   Online sources shown.

# 1
# Introduction,
# Need and Goals

## *Goal, Need, and Plan - 1*

Ubiquitous "3D Wireless" is needed, and Advanced MBRS should and can be its foundation

Currently, the vast majority of wireless is flat-earth bound and thus "2d," and uses wave forms that are also 2d since OAM and similar 3d wave forms cannot work well in NLOS 2d that predominates, and lacks precision in time and space even in 2d (it is fuzzy). This "flat" and "fuzzy" wireless imposes severe limitations, as is imposed when someone cannot balance, see and hear well.[1]

The exceptions are satellite communications and lightly used low spectrum skywave communications [2] [3]. 2d flat-fuzzy wireless lacks the height dimension and with it, LOS propagation, and with that, huge gains in ERP effectiveness, signal-level predictability, vertical polarization, and accurate time transfer (GPS level or better) and thus the basis to securely [see 4] cure the fuzziness via pPNT.

Advanced MBRS will provide 3d wireless nationwide, Continental, and Intercontinental (easily worldwide, when coordinated) in a highly cost effective and secure manner, and provide LOS-based functions including GPS- independent Position, Navigation and Timing ("ipPNT") for a foundation of all "smart" critical infrastructure and services.

Based on Ionosphere heights, advanced MBRS will very cost effectively cover everywhere, even in most remote areas and far offshore (by 1,000 miles or so, and more with relays on ships and islands). The more it is used at base and remote stations, the more capacity is generated. It can deliver nRTK corrections (already for the most part available in the US land mass, via NOAA CORS, etc.) on broadcast basis to everyone at not cost to recipient, and nominal total costs of delivery.

Advanced MBRS will provide 3d wireless because it is based on Ionospheric radio wave propagation, and it will be highly cost effective, and spectrum efficient, due to using the "free" billions of "smart antennas" in the Ionosphere that appear daily by plasma trails created by grain-sized meteoroids that burn up in the Ionosphere creating this plasma trail antennas.[4]

Advanced MBRS 3d wireless will integrate easily with, and extend and protect, other wireless, in many ways, including but not limited to use of and by drones. Advanced MBRS adds other benefits shown below.

[1] Thus, e.g., movement to commercial '5G' is highly difficult and costly. Government, even military government, wireless is further behind on its '5G' including since the developments are so complex that it cannot keep up with the commercial sector.

[2] Troposcatter and HF primarily. But these have far more cost, antenna-size and other limitations vs. advanced MBRS.

[3] And certain military super low frequency, very low data rate signaling through the earth and seas: not considered here.

[4] No hostile party can knock these out or jam them, as is easy to do with GPS. MBRS is far more survivable even in a nuclear attack (surface, or high-altitude EMP to "fry" many electronics) or severe solar flare or coronal mass ejection that also may "fry" these. This is explained in various US government studies and private publications, found online.

## *Goal, Need, and Plan - 2*

*Goal & Need: Nationwide (i) RF private commons, accessible by all, as the foundation of Precise Infrastructure, which is precise Position, Navigation & Timing (pPNT) that augments GPS-GNSS, but is independent, and has high security and robustness. (ii) Secured federal-use capacity.*

*Functions: pPNT-based: (1) GPS-GNSS alternative PNT, (2) natural-environment 'infrastructure' (terrestrial & atmosphere), (3) manmade infrastructure including ITS (intelligent transportation systems), (4) drones (air & ground), (5) improved Ionospheric science, & weather prediction, & engineering (if needed), (6) whitespace broadband, (7) emergency response, (8) encryption security, (9) 5G+ commercial wireless.*

*A - Physical RF & Technical Needs*

Robust and nanosecond synchronized:

① Nationwide RF spectrum (Spectrum) for super range (Range) RF links (Links)

② Spectrum redundancy (RF Redundancy)

③ Link propagation redundancy (Links Redundancy)

④ BoC (best of class) data broadcast links over Range (Broadcast)

⑤ BoC 2-way links over Range (2-Way)

⑥ Chips for core functions (Chips)

⑦ Super-gain base antenna arrays (Base Arrays)

⑧ Improved remote radio antennas (iAntennas) including phased Mesh

⑨ Remote radios fixed and mobile mesh nets (Mesh)

⑩ High redundant encryption (Encryption)

*B - Problems to date (industry- markets) (keyed to #'s under A)*

1. A.1. No one has taken the time and effort but the this group.
2. A. 1-10. Takes too much long-term foresight, research, development. Does not fit in commercial or government business models of any other entity or coordinated group.
3. Others, except higher levels in the US PNT (GPS and related) community, have not understood precise Position, Navigation & Timing or pPNT and why it is the essential need for effective and secure Functions described above. As in quantum physics, space (location) –time (thus navigation) is the foundation or field of matter-energy-observers).

*Pages below give details*

*C – Polaris PNT Solution -*

1. A. 1-3. The A.1 the Spectrum: government has it. Private, including private nonprofit can partner.

   Range, and RF Redundancy, and Link Redundancy are by mid-VHF long range terrestrial Links, and 25-55 MHz Paging super long range terrestrial and skywave Meteor Burst (MB) RF Links.
2. A. 4. Broadcast: Digital Radio Modiale for terrestrial, and one-way next-gen MB for MB Links.
3. A.5. 2-Way: New-gen MB and terrestrial (below).
4. A.6. Chips available and cost effective (below).
5. A.7. Base Arrays: available, based on radio astronomy and earth-atmosphere wide-area distributed phased array advancements (essentially, computer tech applied to simple antenna elements for super-gain, long-range receive and radar).
6. A. 8, 9. Also available now – see below.
7. A. 10. Via MB nanosecond timing and MB plasma-trails' unpredictable-characteristics-based encryption.

** '40' MHz* means 25-55 MHz. / Terranautx is at www.terranautx.com but we do not put some, confidential data there. / The "Private Commons" herein means what the FCC means by this.*

Certain Terms

- 200 MHz - means the ~ 130 - 235 MHz range
- 40 MHz - means the ~ 25 - 55 MHz range (herein, '40' MHz) [1]
- 900 MHz - means the ~ 700 - 1200 MHz range [2]

The same phased array,[3] chip, & other tech is at hand for all 3 ranges for the wireless systems for the Functions described on page 3 above (together, the "Systems"):

------------

Notes

[1] Private and federal spectrum surveys show that a lot of spectrum in this range under NTIA OSM rights, is not in use, and may be available in some may be available in public-private partnerships with federal agencies via NTIA OSM authorization, as we plan.

[2] Among available bands is n-LMS, 14 MHz in bandwidth, for government ITS networks.

[3] E.g., "LOFAR" which means the Low Frequency Array for radio astronomy and certain atmospheric and terrestrial science. "EISTAT" means the European Incoherent Scatter radar facilities, for atmosphere and ionosphere science and prediction, and other purposes. These and other similar facilities, some also noted below, including "KAIRA", use software defined radios and antennas that may be adapted for radio base-station transceivers for expanded purposes, as discussed herein. In abbreviated form, like technologies can be used in remote radio devices, some presented below.

# 2
# Presentation Context

## Context

Public records show a constrained context of this presentation.  There are actions to remove the constraints which, in part involve the following principles of law.

The US Supreme Court stated in *WOW v Johnson*, 326 U.S. 120 ("WOW"):

"… [T]he…Commission's [FCC's] power of granting, revoking and transferring licenses involves proper application … that determine "public convenience, interest, or necessity."…[T]he Nebraska [state court] decree orders…the return of the [FCC] license…. Equally does it prevent WOW from opposing a return…. These are restrictions…upon the licensing system which Congress established…. [B]y controlling the conduct of parties before the … Commission, the court below reached …into matters that do not belong to it…. Accordingly, the judgment is reversed…."

Citing *WOW*, the FCC Commission stated in *In re Arecibo*, FCC 85-462, 101 F.C.C.2d 545:

"… [I]n…*WOW v. Johnson*, supra…. [w]e understand the Supreme Court to have held that, in taking steps to place a matter before the Commission, a court can neither prohibit interested parties from making arguments to the Commission concerning the merits of the matter nor infringe in any way the Commission's exclusive, jurisdiction over licensing matters. See … *WOW v. Johnson*, supra at 130-31. The Superior Court's actions here have not interfered with Arecibo's right to assert before the Commission any argument regarding the assignment applications, and the court specifically left to the Commission the determination of all public interest issues which might be raised by the applications."

See also 28 USC §1498 and its origin: no one can block any US agency from using patented tech, even that may violate state law contract rights.

The above is based on  The Supremacy Clause clause, Article VI of the U.S. Constitution and related exclusive federal jurisdiction and preemption.  The above also assumes First Amendment law.

In sum:  the FCC, and equally the NTIA, and certainly Congress, should protect, for its public-interest purposes, presentation of relevant ideas and information by interested persons, and remove any barriers.  This needed government-purpose protection -  *is in addition to* -  private-purpose First Amendment speech and petitioning.

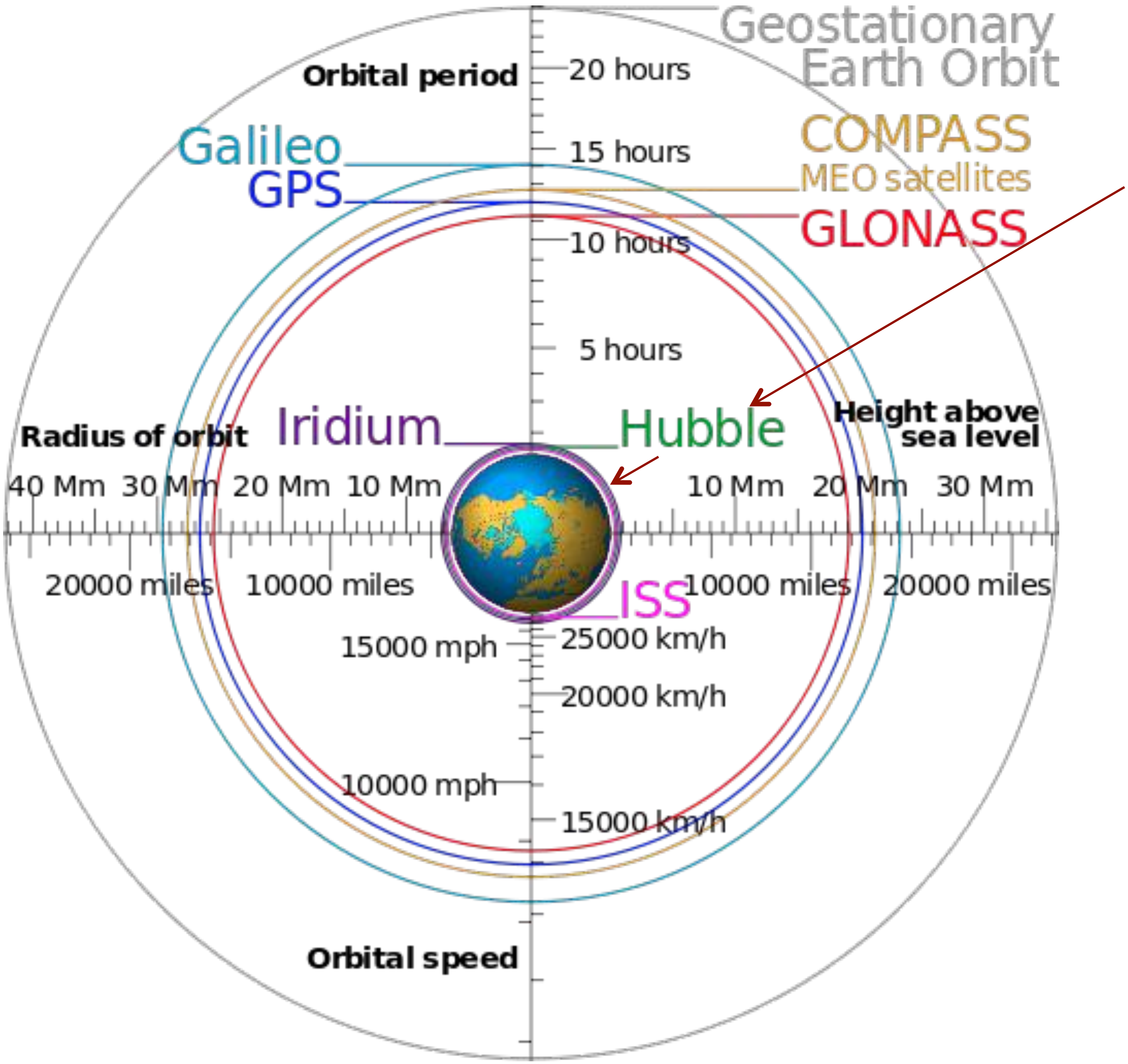
# 3

# PNT

# US PNT* Agencies

* Position, Navigation & Timing

## & Federal Radionavigation Plan




MBRS described uses meteor burst plasma trails in the range of 80-100 km above the earth (height above sea level). (Well Inside **Hubble** orbit shown at left, which is at about 600 km.)

There is a constant series of MBRS plasma trails, billions a day above the earth, that serve as effective "smart antennas" for 25-55 MHz +/- range radio spectrum signaling.

This can provide alternative precise PNT to GPS-GNSS, and one- and two- way communications as well.

In addition, it can provide faster time transfer, and more secure encryption, versus other methods, which is critical for data networks for critical infrastructure and services.

From the 2015 Federal Radionavigation Plan: see next page.

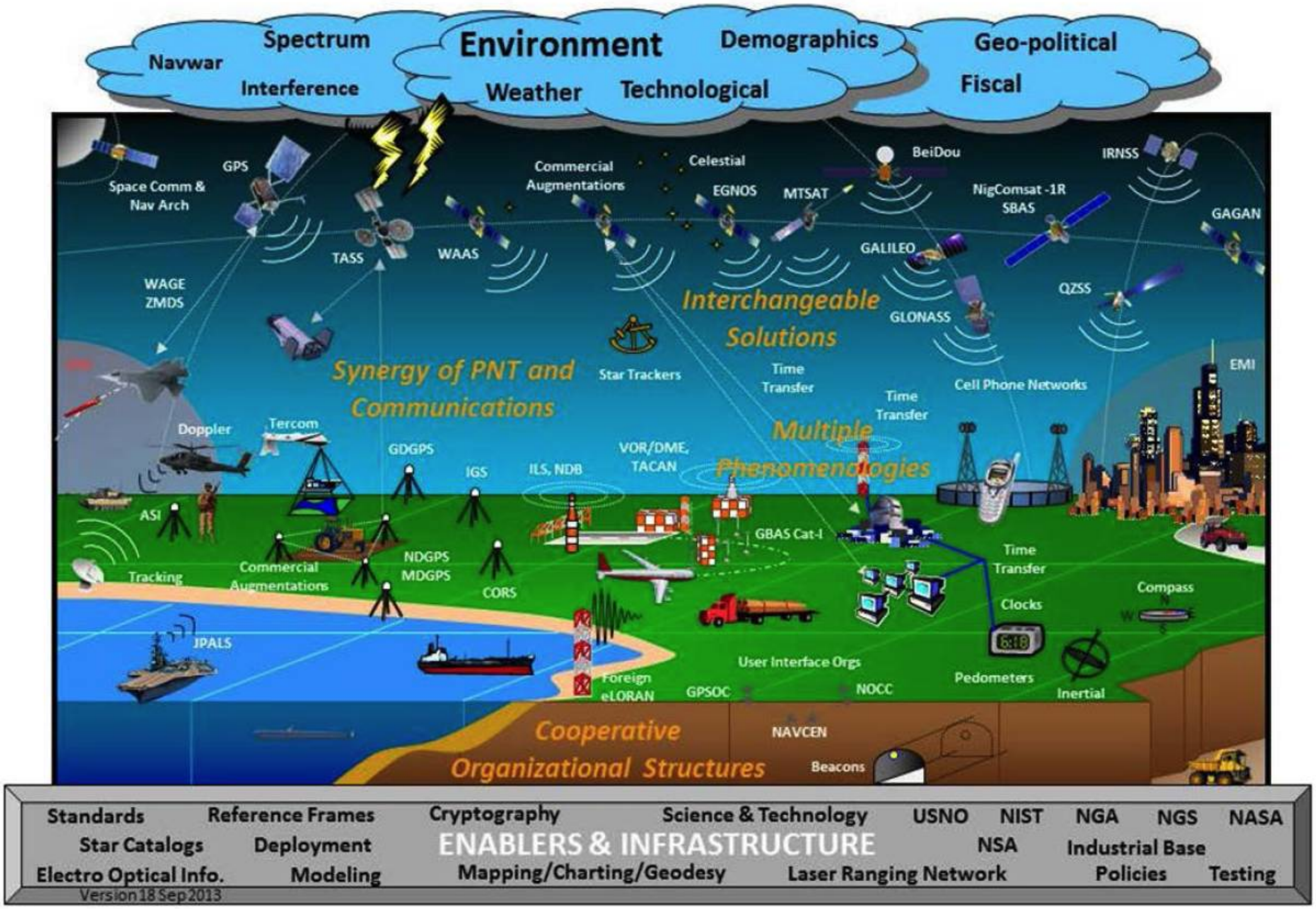



**Figure 6-1 National PNT Architecture (2025)**

The advanced MBRS proposed herein would provide a continent-wide foundation of Position, Navigation and Timing (PNT) functionality that augments, but also operates in fully independent mode, to the space-based and terrestrial PNT functions depicted above. It also would provide increased MBRS encryption to substantially improve security, and be more robust and resilient in any space or terrestrial attack versus.

http://www.navcen.uscg.gov/pdf/FederalRadionavigationPlan2014.pdf

# 2014 Federal Radionavigation Plan [marked excerpts ]

Ashton B. Carter
Secretary of Defense
Date: MAY 19 2015

Anthony R. Foxx
Secretary of Transportation
Date: 2-23-15

Jeh C. Johnson
Secretary of Homeland Security
Date: May 5 2015

The FRP contains chapters covering Roles and Responsibilities, Policy, representative PNT User Requirements, Operating Plans, and the National PNT Architecture, as well as appendices covering System Parameters and Descriptions, PNT Information Services, and Geodetic Reference Systems and Datums. It is updated biennially, allowing more efficient and responsive updates of policy and planning information. Your suggestions for the improvement of future editions are welcomed.

While the growth in civil and commercial applications continues, PNT information provided by GPS remains critical to U.S. national security. Likewise, the continuing growth of services based on the GPS presents opportunities, risks, and threats to U.S. national, homeland, and economic security. The widespread and growing dependence on GPS of military, civil, and commercial systems and infrastructures has made many of these systems inherently vulnerable to unintentional interruption and likely targets of intentional attack on PNT services. Therefore, the U.S. must continue to improve and maintain GPS, augmentations, and backup capabilities, in order to meet growing national, homeland, and economic security requirements, civil requirements, and commercial and scientific demands.

PNT services have historically been provided from ground based systems. As the full civil potential of GPS services and its augmentations are implemented, the demand for services provided by other federally provided PNT systems is expected to decrease. The USG will reduce non-GPS-based PNT services with the reduction in the demand for those services. However, it is a policy objective of the USG not to be critically dependent upon a single system for PNT. The USG will maintain backup capabilities to meet: (1) growing national, homeland, and economic security requirements, (2) civil requirements, and (3) commercial and scientific demands. Operational, economic, safety, and security considerations will dictate the need for complementary PNT systems. While some operations may be conducted safely using a single PNT system, it is Federal policy to provide redundant PNT service where required. Backups to GPS for safety-of-life navigation applications, or other critical applications, can be other PNT systems, or operational procedures, or a combination of these systems and procedures, to form a safe and effective backup. The FAA is

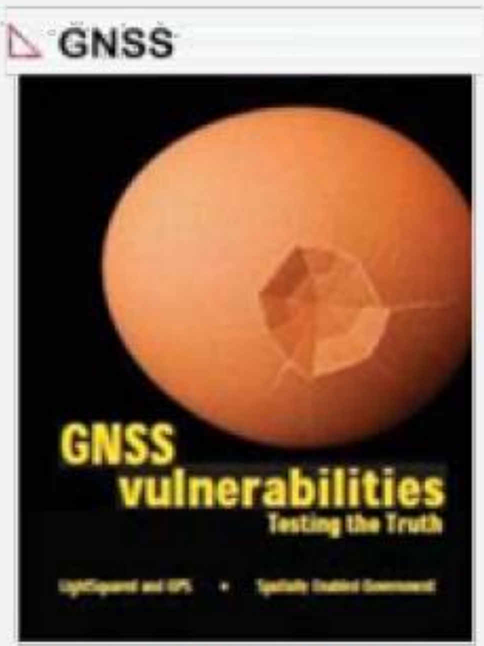
Real-time carrier phase differential positioning is increasingly employed by non-navigation users. Currently, this requires a GPS reference station within a few tens of kilometers of a user. In many cases, users are implementing their own reference stations, which they operate only for the duration of a specific project. Permanent reference stations to support real-time carrier phase positioning by multiple users are currently provided in the U.S. primarily by private industry. Some state and local government groups are moving toward providing such reference stations. Other countries are establishing nationwide, real-time, carrier phase reference station networks at the national government level.

For automobiles and other land navigation systems, Intelligent Transportation System initiatives seek to leverage the synergy of PNT and communications in areas like Connected Vehicle Research. As envisioned, a system of connected vehicles has the potential to transform travel through interoperable wireless communications networks. The technology will enable cars, trucks, buses, and other vehicles to "talk" to each other and road infrastructure to continuously share important safety, mobility, and environmental information. Vehicle-to-vehicle communication systems may also factor into Positive Train Control initiatives as researchers explore ways to integrate GPS into communications systems that could warn trains and cars of potential collisions at railroad crossings.

The advanced MBRS proposed herein would provide for what is underlined above: a continent-wide foundation of Position, Navigation and Timing (PNT) functionality that augments, but also operates in fully independent mode, to the space-based and terrestrial PNT functions in this plan (depicted in page above). It also would provide increased MBRS encryption to substantially improve security, and be more robust and resilient in any space or terrestrial attack versus.

# GNSS Vulnerabilities are a Major Concern

Symmetricom




COORDINATES MAGAZINE
March 2012

Royal Institute of Navigation
Science Technology Practice

7th ANNUAL
GNSS VULNERABILITIES AND SOLUTIONS CONFERENCE
18 – 20 April, 2013

U.S. Department of Homeland Security

"Maintains a central database for reports of domestic and international interference to civil use of GPS …"

**U.S. GPS Interference Detection and Mitigation (IDM) Program**

**GNSS vulnerability is a growing concern in critical infrastructure applications**

# Everyday GNSS Outages (Unintentional)

Symmetricom

## Mechanical, Human Error

Antennas are easily damaged and can interfere with each other


Human error in GNSS system operations

GPS cable conduit dangling in the wind

Harmonics or radiation from nearby electronics, failures or misaligned transmission equipment

## Natural, Environmental

Lightning hits and high winds take out antennas, antenna icing

Solar flares, atmospheric phenomena

Foliage causes signal masking

# Everyday GPS Outages (Intentional)

Symmetricom

## Jammers and Spoofing

Jammers

$55 Ebay

$83 GPS&GSM

Spoofing

**Cheap jammers to sophisticated spoofing**

Signal Characteristics of Civil GPS

Devices which claim to jam or "block" G… are widely available through a number of we… online entities. The cost of these devices ra… a few tens of dollars to several hundred. T… does not seem to correlate with the claims… the purveyors of these devices regarding th… and effectiveness of the product in question… ranges from a few meters to several tens… are advertised, but it will be shown that… effective ranges are significantly greater. Cl… true power consumptions range from a fra… Watt to several Watts.

## Software attacks

GPS Software Attacks

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ABSTRACT

In this work, we systematically map out a larger attack surface by viewing GPS as a computer system. Our surface includes higher level GPS protocol messages than previous work, as well as the GPS OS and downstream dependent systems. We develop a new hardware platform for GPS attacks, and develop novel attacks against GPS infrastructure. Our experiments on consumer and professional-grade receivers show that GPS and GPS-dependent systems are significantly more vulnerable than previously thought. For example, we show that remote attacks via malicious GPS broadcasts are capable of bringing down up to 30% and 20% of the global CORS navigation and NTRIP networks, respectively, using hardware that costs about the same as a laptop. In order to improve security, we propose systems-level defenses and principles that can be deployed to secure critical GPS and dependent systems.

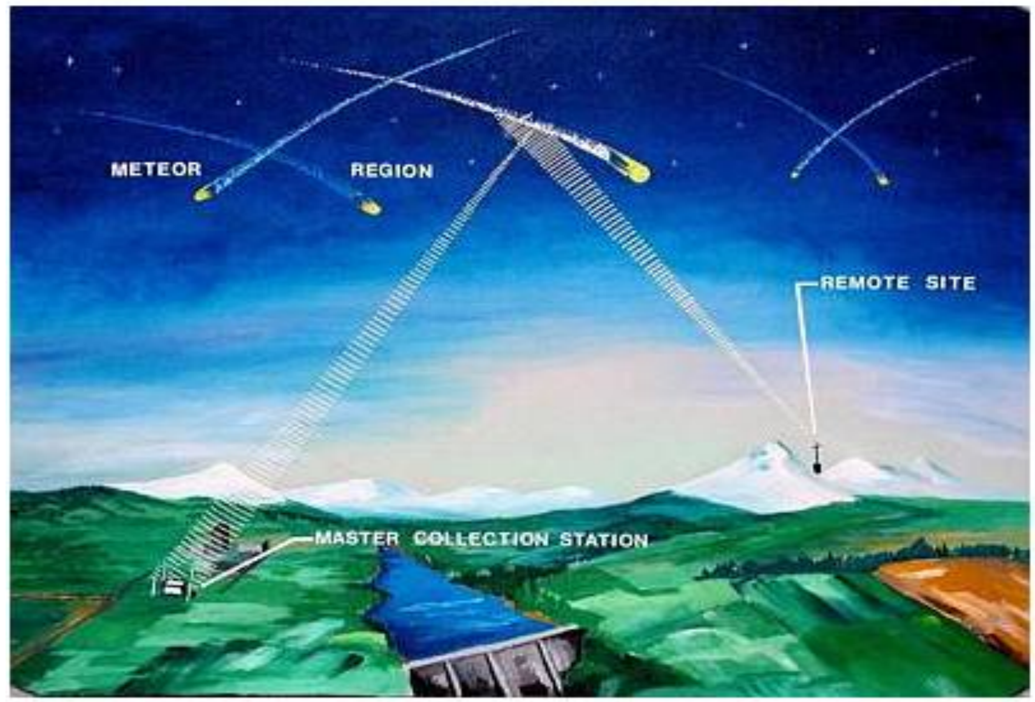
# 4 - 7
# What is MBRS
# and Advanced MBRS

The National Water and Climate Center (NWCC) has developed efficient and highly effective technology to provide the data needed for water supply, climate, analysis, and conservation planning. NWCC acquires additional data sets that are needed from other networks and designs local data networks and sophisticated national networks. NWCC operates a variety of networks that use different data acquisition technology. We offer our expertise to others through documentation, training, partnership, on-site assistance, and participation in professional forums. Briefly, some of the types of data acquisition technology that are currently established are:

Note. NRCS SNOTEL shows MBRS is successful for NCRS's critical purpose. Advanced MBRS discussed herein may, under on plan, complement SNOTEL in a 'partnership' – see left.

## Meteor Burst Communication Technology

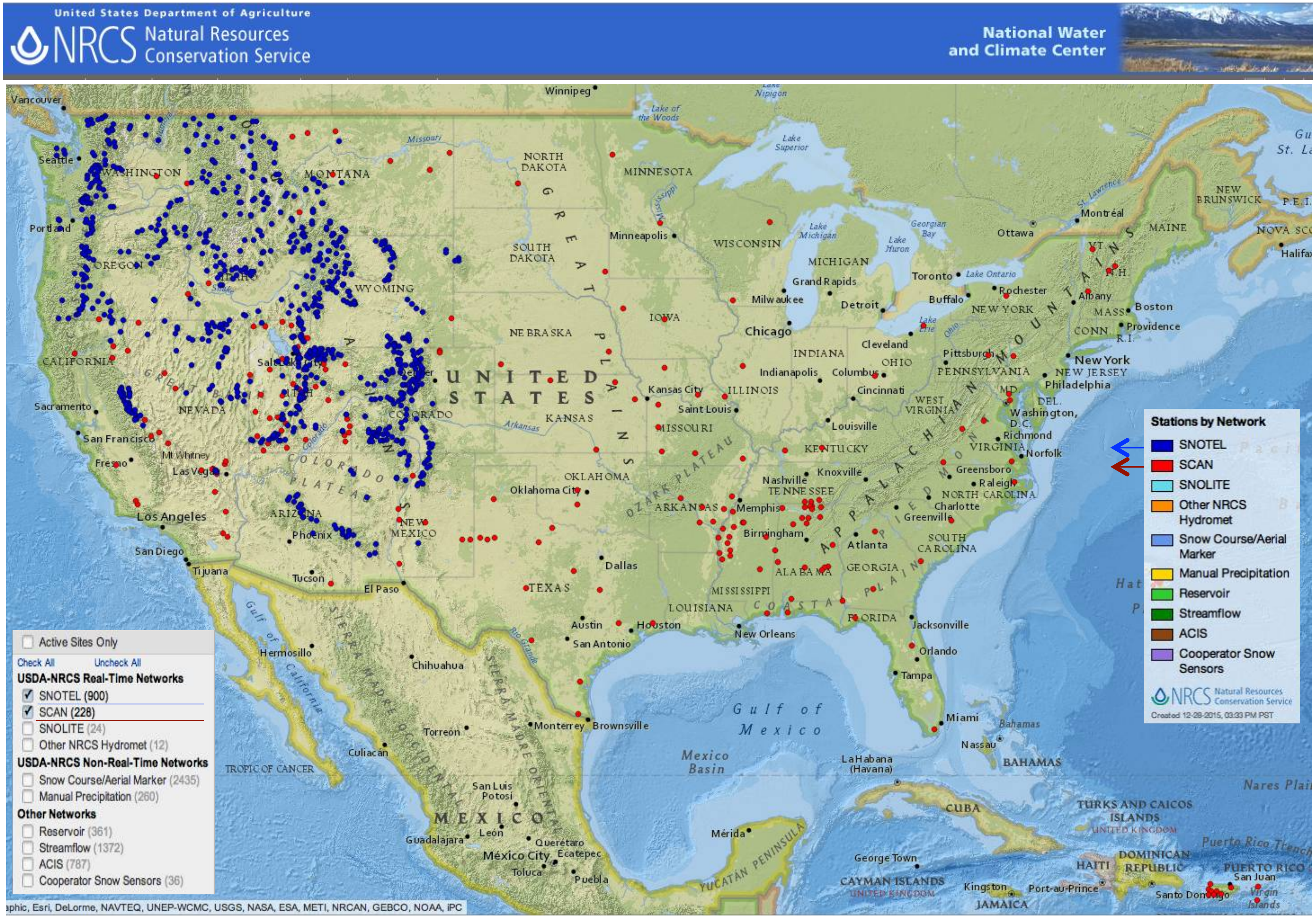
Meteor burst communication was discovered by the military in the 1950's. NRCS implemented this technology and developed SNOTEL in 1975. Meteor burst communication uses the billions of sand sized particles (1 gram or larger) that burn up in the 50 to 80 mile high region of the atmosphere to relay radio signals back to the earth. This technique allows communication to take place between remote sites and a master station up to 1200 miles away. At the master station, the remote site data is checked for completeness. If so, an acknowledgment message, returning over the same path, tells the remote site not to transmit again during this polling period. The entire process takes place in less than a tenth of a second. Meteor burst communication has proven to be extremely reliable. From the master stations, the data are sent via telephone line to the NWCC Central Computer Facility.



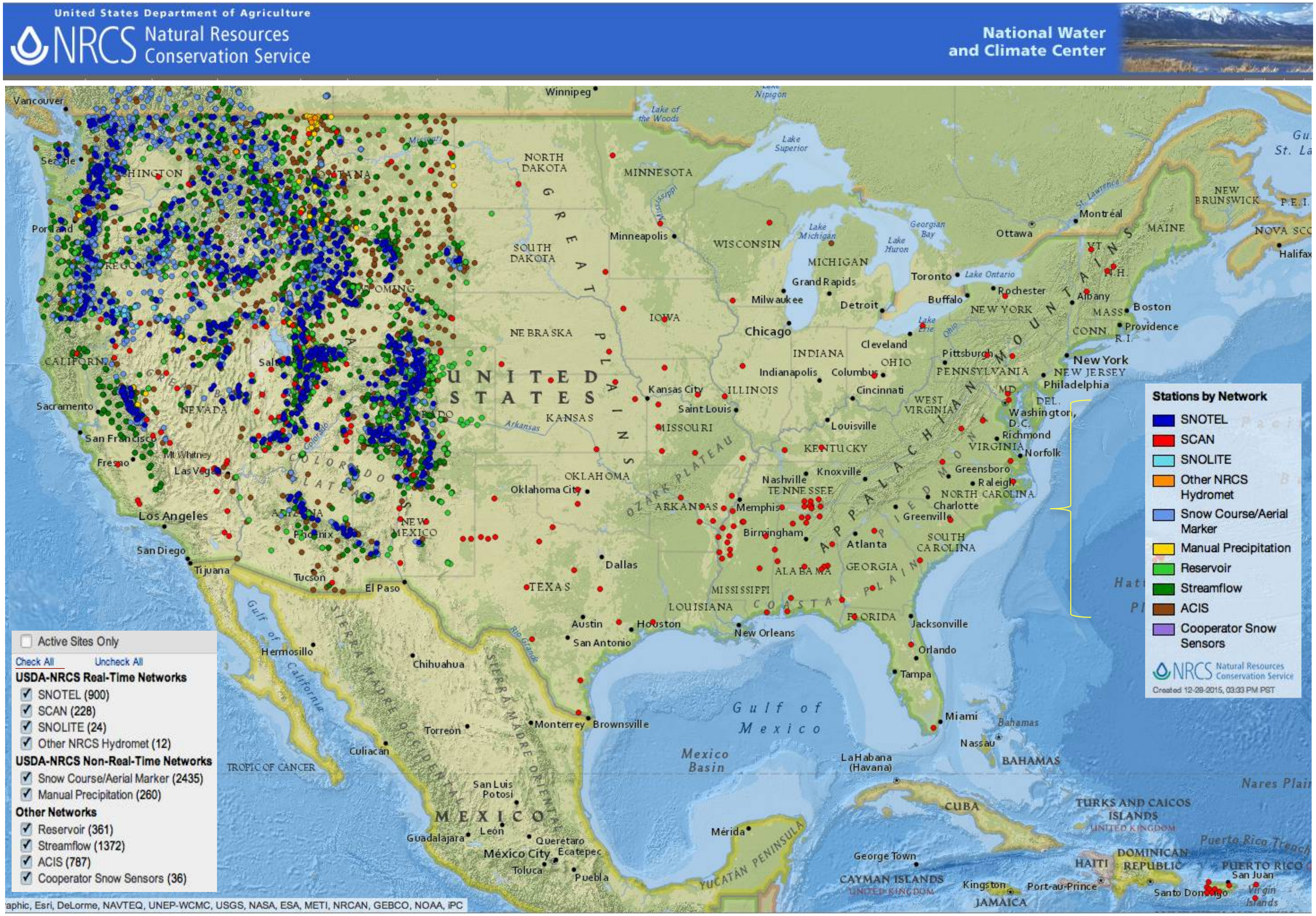

### Electronics Maintenance Facility

The NWCC operates a SNOTEL electronics maintenance facility that maintains a fully functional complement of modular SNOTEL components that can be sent overnight, worldwide if a component fails. The facility also repairs data acquisition systems sent in from the field, designs custom interface boards, tests sensors, keeps abreast of latest technology, and provides answers to technical questions related to data acquisition technology.

Note: Above excerpts are from: http://www.wcc.nrcs.usda.gov/publications/Briefing-Book/bb25.html. Maps of NRCS SNOTEL remote stations are on following pages.




Note: This shows the current MBRS-based SCAN and SNOTEL stations (SCAN is described below). SNOTEL - 900 stations. SCAN - 228 stations (see legend bottom left). The next slide displays all of these NRCS "Networks" stations in the legend. The map was generated at the NRCS online interactive mapping tool, on 12-28-14. I unchecked "active sites only," since doing so showed a few more stations (those apparently not "active" at this date).




Note: This shows the current MBRS-based SCAN and SNOTEL stations, and all other of these NRCS "Networks" stations in the legend. *Cost effective advanced MBRS as described herein could serve all these, and tens of thousand or more, stations to monitor and protect the environment, get data for better prediction and regulation, etc.* The map was generated at the NRCS online interactive mapping tool, on 12-28-14. I unchecked "active sites only," since doing so showed a few more stations (those apparently not "active" at this date).

**Management of Natural and Environmental Resources for Sustainable Agricultural Development**

**Proceedings of a Workshop**

November 2008

USDA United States Department of Agriculture

NRCS Natural Resources Conservation Service

WMO OMM World Meteorological Organization Agricultural Meteorology Division

World Agricultural Outlook Board waob

Over the past two decades, there has been an increasing awareness of the potential damages that climate change, air and water pollution and inadequate natural resources management could induce upon human health, natural ecosystems and the economy. To address these concerns, considerable emphasis has been placed on sustainable development by many countries and international organizations. Accordingly, sustainable agricultural development has become a

## The U.S. Department of Agriculture's Natural Resources Conservation Service Soil Climate Analysis Network

There is a need for a national network that provides near real-time soil moisture and temperature data combined with other climate information for use in natural resource planning, drought assessment, water resource management, and resource inventory. In 1991, a 10-year pilot project was started to test the feasibility of such a network. Initially, 21 stations were established in the pilot project. Over the span of the project, an array of above ground and below ground sensors were tested along with a unique meteor burst communication system. This pilot led to the development of the Soil Climate Analysis Network (SCAN). The network now has 115 stations, of which most have been installed since 1999, located in 39 states. The stations are remotely located and collect hourly atmospheric and soil moisture and temperature data that is made available to the public via the Internet. Future plans for the network include locating new stations on benchmark soils, increasing the number of stations, making data summaries more user-friendly, and increasing data quality.

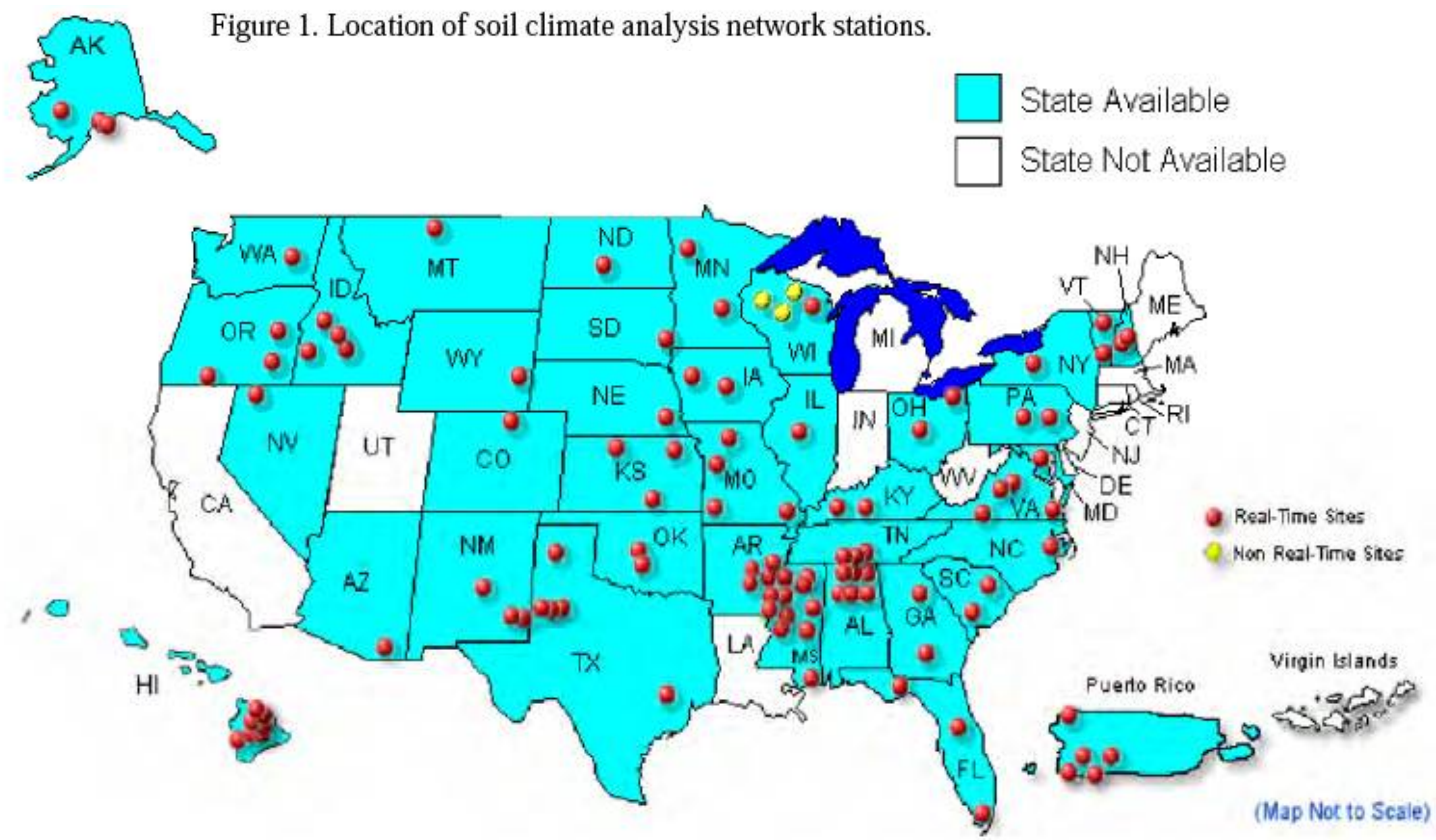
Note: This was a major international conference on the topic at top left- and, now even more critical, with increasing evidence of "global warming" in high probability to stop the causes and effects.

US DOA NRSC presented its meteor-burst communication (an aspect of MBRS) SCAN system and expansion plan.

SCAN is like SNOTEL – both use MBRS and both are by DOA NRCS.

The advanced MBRS presented in these slides can assist and expand SCAN and SNOTEL, among other federal and federal-goal programs.

Figure 1. Location of soil climate analysis network stations.




The advanced MBRS presented in these slides can assist with this planned* expansion of MBRS-based SCAN, including by the proposed public/ private-nonprofit / private "partnerships', and strong economic viability.

Federal agencies involved, here- DOA, would primarily provide radio spectrum and some core wireless network facilities, and the private sides would provide Capex and Opex capital, and other recourses needed.

The current network is comprised of 113 stations, which are located in 39 states (Figure 1).

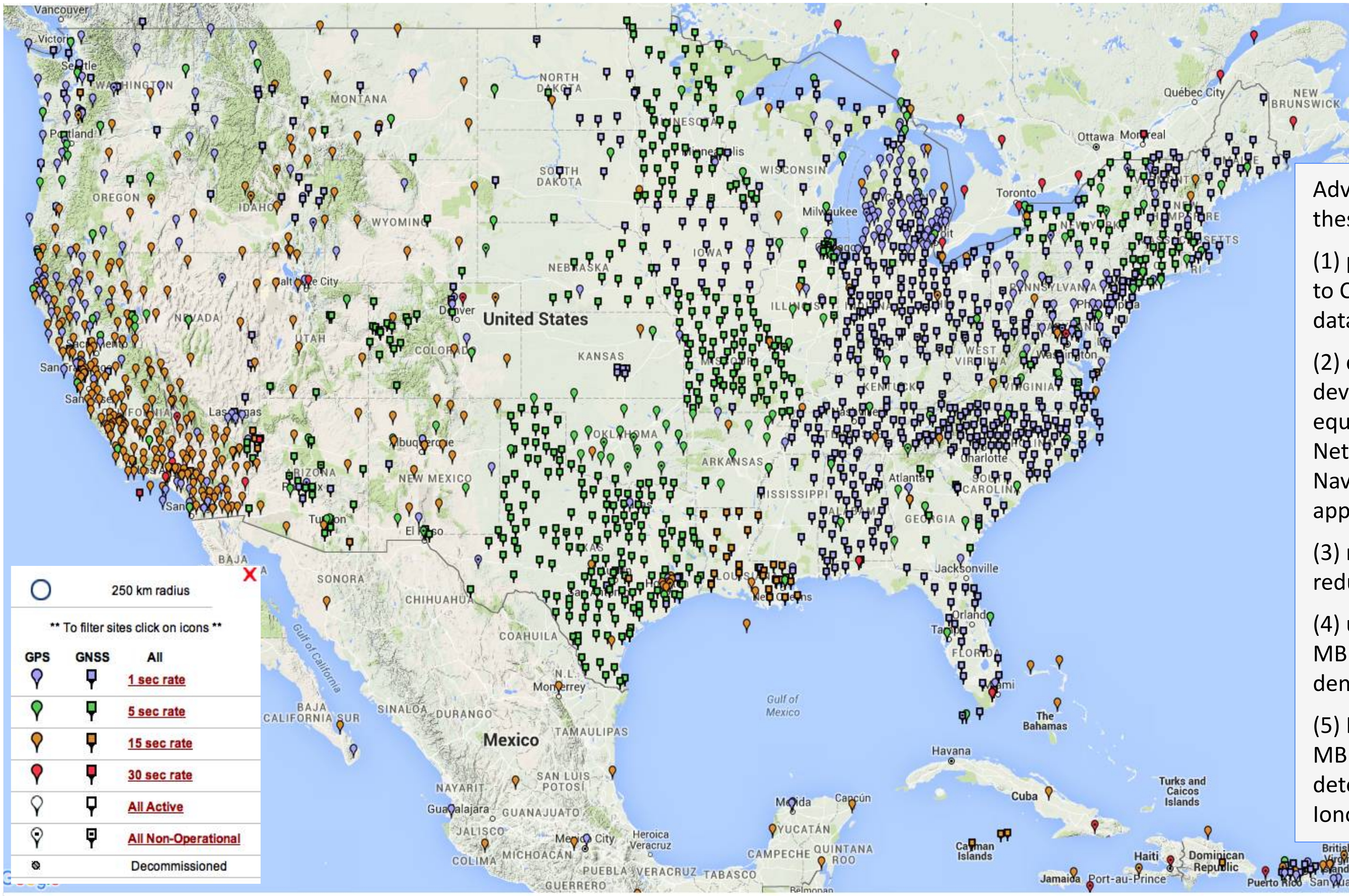
Under the proposed full implementation of SCAN, more than 1,000 new remote sites would be added (USDA-NRCS, 2004). This would be accomplished by (1) integrating information from existing soil-climate data networks and (2) establishing new data collection points through partnerships with Federal, state, local, and tribal entities. This design will support natural resource assessments and conservation activities well into the 21st century; however, the full implementation of SCAN is dependant upon additional funding.

* Above from the proceedings of the 2006 conference. A map of the current, end-2015, SCAN stations is on a slide several slides above.

# CORS Map

National Geodetic Survey

http://www.ngs.noaa.gov/CORS/




Advanced MBRS presented in these slides can:

(1) provide wireless data links to CORS stations to transmit data to the networks involved,

(2) deliver CORS data to rover devices with nRTK GPS-GNSS equipment (in Real-Time Networks) for precise Position, Navigation and Timing applications (pPNT),

(3) more secure wireless, and redundancy, and lower cost,

(4) use the CORS data for MBRS ipPNT (GPS- independent pPNT).

(5) Improve CORS data by MBRS multistatic radar detection and prediction of Ionospheric conditions.

The National Geodetic Survey (NGS), an office of NOAA's National Ocean Service, manages a network of Continuously Operating Reference Stations (CORS) that provide Global Navigation Satellite System (GNSS) data consisting of carrier phase and code range measurements in support of three dimensional positioning, meteorology, space weather, and geophysical applications throughout the United States, its territories, and a few foreign countries.

Surveyors, GIS users, engineers, scientists, and the public at large that collect GPS data can use CORS data to improve the precision of their positions. CORS enhanced post-processed coordinates approach a few centimeters relative to the National Spatial Reference System, both horizontally and vertically.

The CORS network is a multi-purpose cooperative endeavor involving government, academic, and private organizations. The sites are independently owned and operated. Each agency shares their data with NGS, and NGS in turn analyzes and distributes the data free of charge. As of August 2015, the CORS network almost 2,000 stations, contributed by over 200 different organizations, and the network. continues to expand.

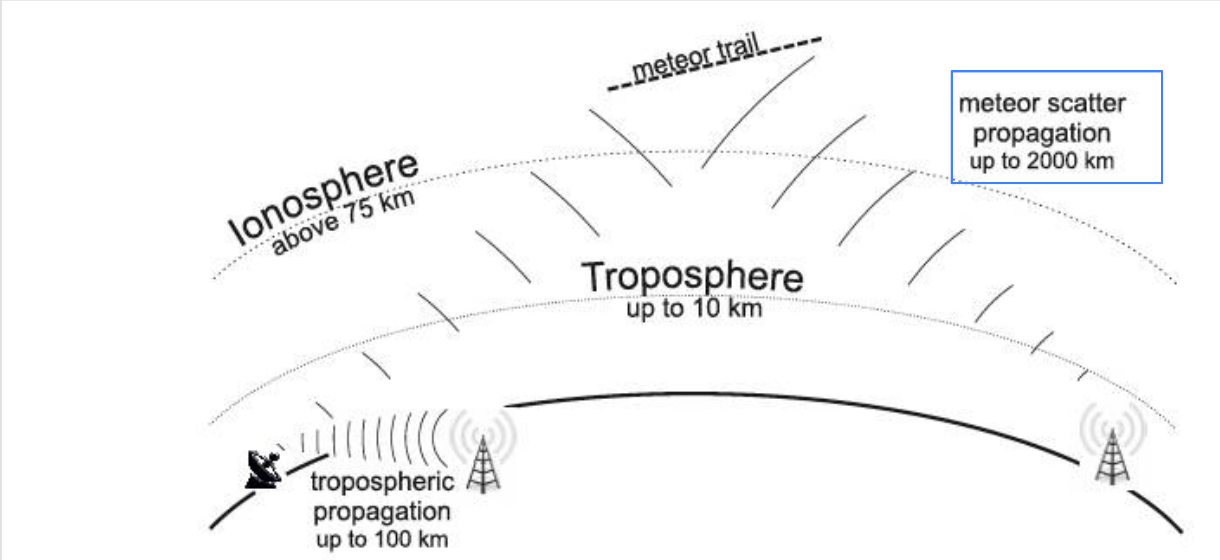



Fig. 1.— The principle of meteor scatter phenomenon.

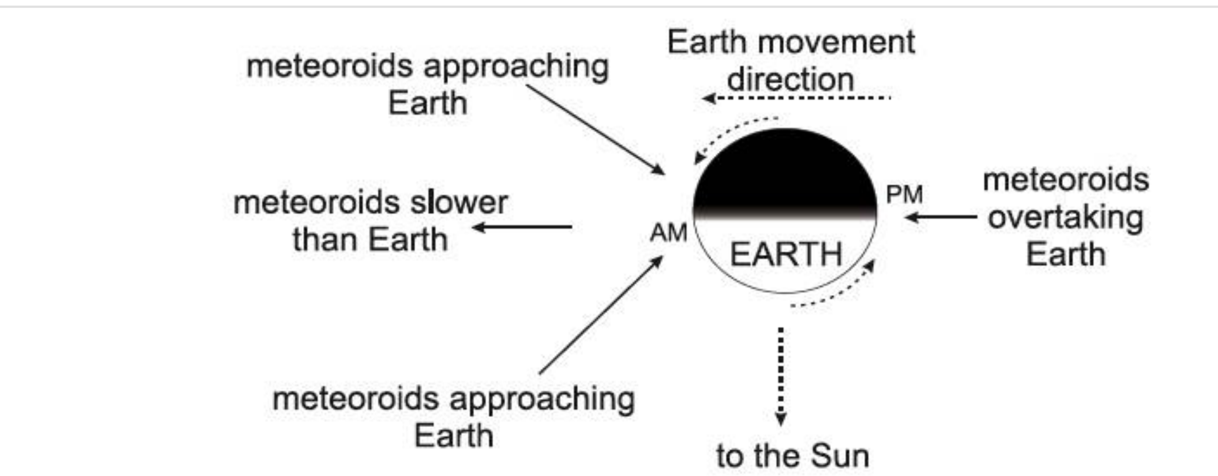



Fig. 2.— The visualization of the Earth in meteoroids environment.

Note: Copy at: http://arxiv.org/pdf/1505.02366.pdf / Other depictions of MBRS elements are provided below.

Note: The most complete work on "traditional" MBRS is:

Meteor Burst Communications: Theory and Practice, Donald L Schilling, editor. Wiley, 1993. See following pages.

Traditional MBRS is all that can be found in coherent form in public records, even current papers.* I have found indications of "advanced" MBRS in development in China and Russia, but the details do not appear to be publicized, and the authors and institutions do not respond to my inquires. In any case, I believe I have a more full and effective approach outlined herein.

The advanced MBRS outlined herein probably exceeds 1,000-fold in total performance and value as compared to "traditional" or modestly augmented MBRS found in most all papers on MBRS.

This is supported by assumptions using best-available MBRS system parameter data and what-if calculations.

-----

* E.g. http://www.ijetie.org/articles/IJETIE_201518006.pdf

Detection of Meteors by RADAR
© Dr David Morgan 2011

## Meteors

What are they – where do they come from?
There are two main sources of small particle debris that constitute meteoroids….asteroids and comets…. Figure 2.1.

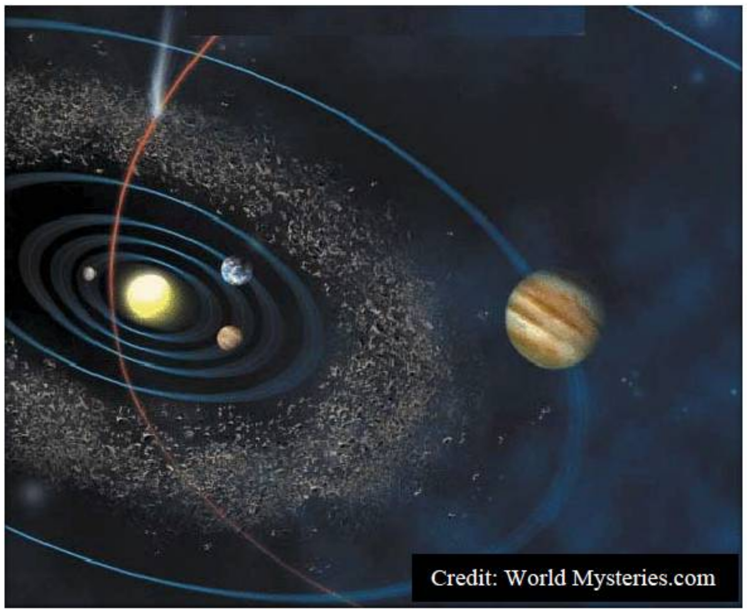



Figure 2.1
Comets and Asteroids as the source of Meteoroids

## Meteor trails

Meteor trails are formed when tiny particles, maybe the size of a grain of sand or smaller (see Figure 2.3) impact the Earth's upper atmosphere at a height of around 90km and generate a

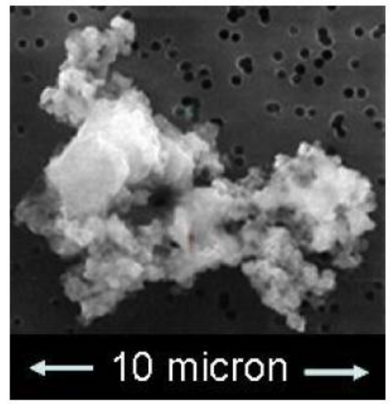



Figure 2.3
Example of a Meteoroid Particle

strong shock wave in the air. There is a huge temperature differential generated across the shock boundary and the radiant heat vaporizes the surface of the particle. This causes the ablation of the particle and ionization of the atoms of the material….

The vaporized material and ionized air play a large part in reflecting electromagnetic waves at radio frequencies – thus enabling their detection by VHF radar.

Here we examine the way the incident radar wave interacts with the ionized trail.  In Figure 3.3 we see the wave approaching a stream of ionized particles represented by a mix of positive ions, negative electrons and neutral molecules.  It is only the electrons that respond significantly to the electric field in the incident wave.  The ions are heavy and do not move a significant amount and play little part in re-radiation of the pulse.  The neutral molecules carry no net charge and cannot interact with the wave electric field.  The strength of the returned signal is dependent on…electron density in the trail… this varies with time, so does the signal strength.

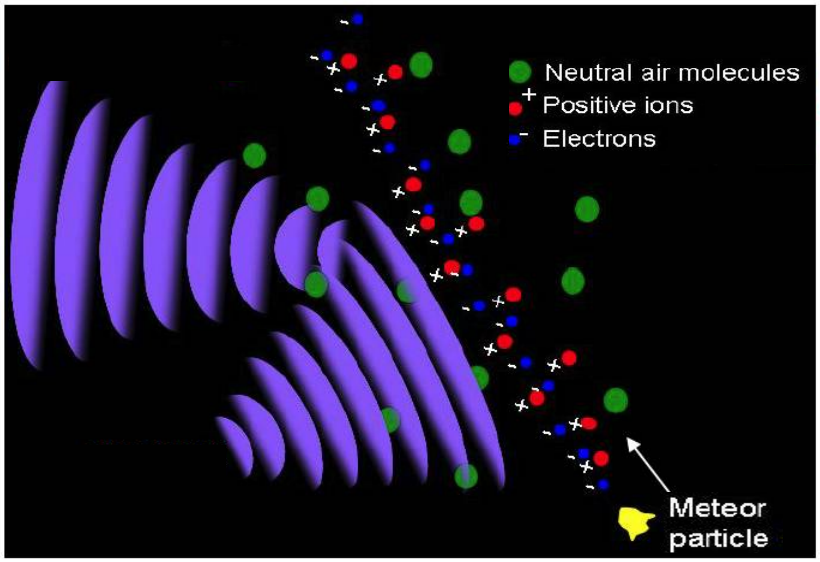



Figure 3.3   Wave interaction with the Ionization Trail

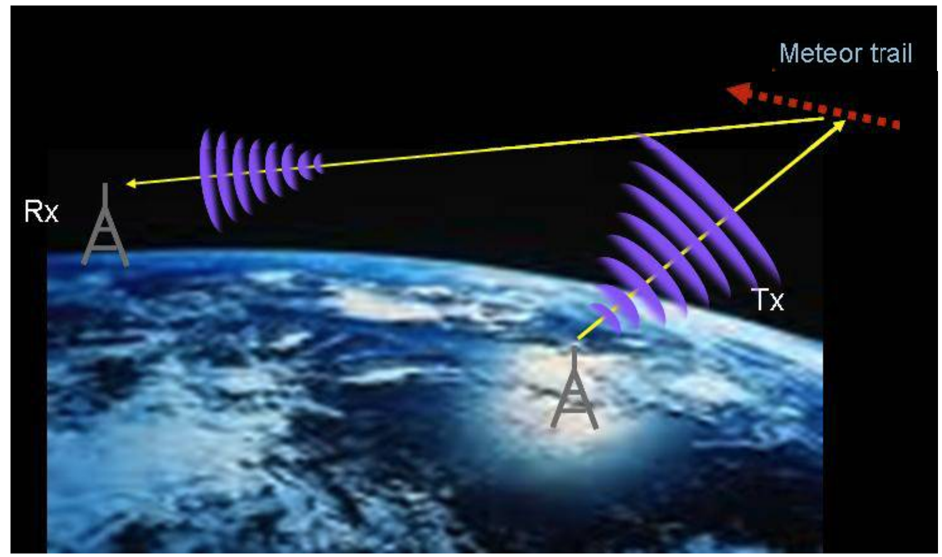
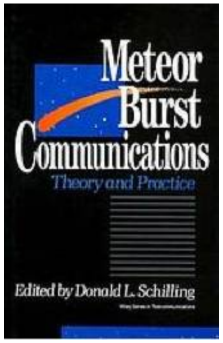



Figure 4.4   Reflection from a meteor trail

*Meteor Scatter* communication systems are highly efficient in its use of the radio spectrum. Radio frequencies are a scarce commodity and the increasing appetite for information demands economical use of the radio spectrum. Because in a large service area different users are "served" by different meteors, interference between the users is virtually ruled out, even if the same frequency is used over a very large area. In this way, the whole of Europe can be served by using only one or two channels, dependent upon the configuration of the communication network.

Note: The advanced MBRS outlined herein probably exceeds 1,000-fold in performance and value as compared to "traditional" or modestly augmented MBRS found in most all papers on MBRS, including the most advanced MBRS described in this 1993 book.




Meteor Burst Communications:
Theory and Practice
Donald L Schilling, editor. Wiley, 1993

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Part 1 below is from Mr. Shilling's oral history
Part 2 below has experts from the book

Part 1 From: http://ethw.org/Oral-History:Donald_Schilling

I co-authored 12 texts and more than 200 papers. I advised more than 75 Ph.D. students, many of who wrote their Ph.D. dissertations on CDMA related topics. In the 1960's I was involved with adaptive delta modulation, a voice digitization technique which was used by the military at that time; it is still used to perform analog to digital conversions.... I did the work initially for NASA, then after NASA I did it for the Army, and then for several other government agencies.

After the adaptive delta modulator I became involved in meteor burst communications, which was a wireless system used to transmit signals beyond the line of sight, using the meteor channel. Meteors are formed all the time, and we bounced our waves off of the meteors. If you do it right, you can get continual voice. A lot of this was done for the Air Force in Anchorage, where they transmitted between Anchorage and Kozebue, which is a city in Alaska right off the Russian border across the Bering Sea. It was a lookout station, and there was no real ionosphere to communicate back and forth, so they communicated off the meteors. We built the equipment and demonstrated that continual voice could actually be achieved if it was done properly. We had an adaptive system.

I edited a textbook for ... Wiley on Meteor Burst Communications, which dealt with that whole area.

Part 2

....Today, we know that to be true because man has walked on the moon, space travel has become... common..., high-energy lasers are used in the medical...and other areas, communication satellites carry voice and data circuits to all points of the globe, and there is meteor burst technology. Meteor burst technology? ["MB"] What's this? Are we bursting meteors? No, just another communications medium...until the early 1970s...virtually ignored.

Discovered in 1935 by a gentleman named Skellet, the technology was considered antediluvian in face of the then current communication systems.... Skellet found that when a meteor entered the earth's atmosphere, the denser air caused the meteor to heat up and eventually burn, creating an ionized trail. He discovered that the ionized trail could be used to bounce a radio signal back to earth. Scientists have known for decades that the earth is continually bombarded by meteors.... One hundred billion meteors have been estimated to enter or pass through the earth's atmosphere in a 24-hour period.

From the 1950s through the 1970s, meteor burst technology was studied and actual tests were conducted to determine the feasibility of using the meteor trails to an advantage. The result of that research produced some interesting information....

Ionized trails were found to have a lifetime of only a few tenths of a second, creating the need for rapid exchange of communication. The transmission rate had to be very fast (a burst of data if you will) to take advantage of the ionized trail. Hence the term "meteor burst" was coined. [U]ntil the availability of integrated solid-state micro-computers, meteor burst as a communication medium was not considered practical except for slow-speed data.... * * * * These short-lived... signals, or meteor bursts, may last from several milliseconds to many seconds.

Signal duration depends on trail line density, initial radius, diffusion rate, electron attachment and the state of upper atmospheric winds. Digital communications is possible during these brief, intermittent meteor bursts, thus forming the basis for an over-the-horizon digital radio link. Since persistent meteoric ionization useful for trail-scatter occurs between 80 and 120 km above the earth's surface, maximum propagation distances of 2400 km are possible. The maximum usable distance for communications, however, is generally below 2000 km because of earth blockage, terrain obstructions, and antenna pattern ground tuck. The time dependence of the trail-scattered RSL depends on the electron volume density in the meteor trail as well as atmospheric parameters.... * * * *

The Alaskan Air Command was the first to install a high-powered, 8kb voice-synthesized MB system as an operational commun-ication medium. Uniquely designed, it supports the operational requirements for Air Sovereignty in Alaska. Other uses may come to light that will parallel those of the Alaska Air Command. However, there will always be a need for inexpensive data systems within the military and in industry. Currently, NORAD is testing a C3 meteor burst network that will connect the Continental United States, Alaska and Canada.

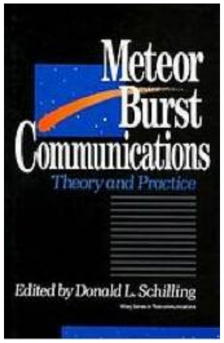
The Alaska National Guard recently installed a MB system that ties the headquarters to remote locations throughout the state. Again, the cost of acquiring a MB system is considerably less than that of other systems, especially in the Alaskan environment. Other countries are now looking into the benefits of a MB system for specific applications, applications where great distances are involved and civil engineering support is too costly for other remote systems. A MB system has been installed between Sondres- trom AB and Thule AB, Greenland. The north-south link operates be- tween 45 and 104MHz. The system is a test bed to investigate performance during polar cap absorption (PCA) events.
...Popular Mechanics that described a MB system for truckers....

In the tactical arena, small portable transceivers could be used by the military in a variety of applications such as resupply nets, status of forces nets, intelligence nets, and others. The Navy could make use of a MB unit that was released under water and brought to the surface by buoy. This application would enable communications while minimizing detection. An oil platform out in the middle of a sea is the ideal application for MB. Red Cross and Civil Defense organizations could use portable MB systems to provide logistic support during natural disasters such as earthquake, flood, and fire. Alarm systems, emergency or logistical networks, and similar systems could be provided in remote locations at a fraction of the cost of comparable systems. Anywhere there is a need for data, MB is an inexpensive alternative that warrants consideration. The applications are limitless and await only the imagination of the far-sighted.... * * * *

It is true that faster is better in terms of system processing times.... However, there are applications where "instant" is not part of the vocabulary. The Alaska SNOTEL net is a good example. Meteorological information is required on a regular basis; however, it is collected over a 24-h period. A slow data base update is acceptable and is tailored to the data collection requirement. The prerequisite for that system is that the data must get through in a timely manner....

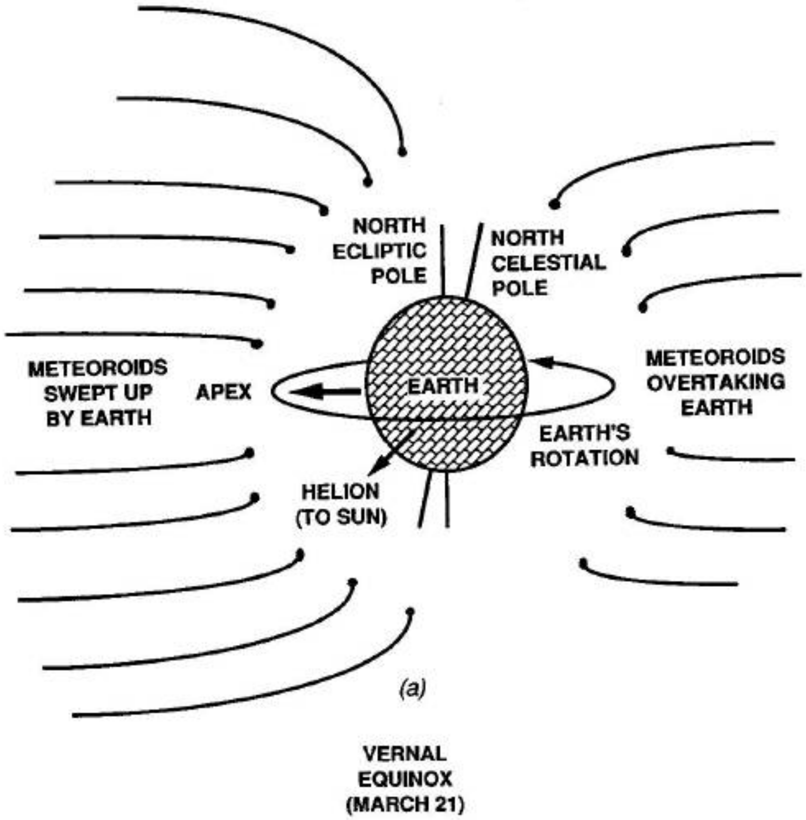
One only need analyze the basic information requirement, that is, life-cycle and time-to-live needs, to make decisions in choosing a baseline communications medium. Immediate update is not always the best answer to an equation.... In spite of the popular demand for more speed, systems like meteor burst still fill special application needs. Certainly, MB systems can be designed to perform as quickly as other systems through the use of new products now available in today's market.

In terms of cost, survivability, and intrusion resistance, meteor burst is hard to beat. Furthermore, it has that special Buck Rogers mystique... how else MB can be used.

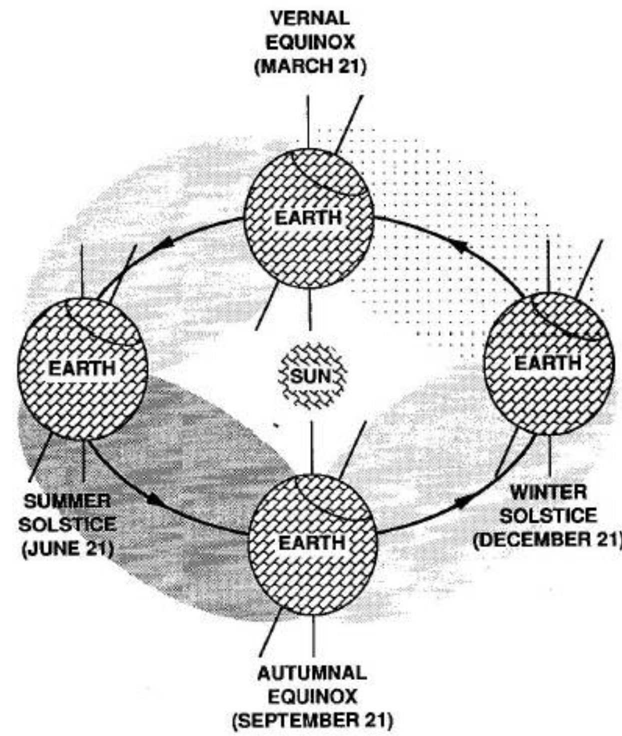



The following depictions are also (as are the introductory text excerpts above) from the book: Meteor Burst Communications: Theory and Practice . Donald L Schilling, editor. Wiley, 1993

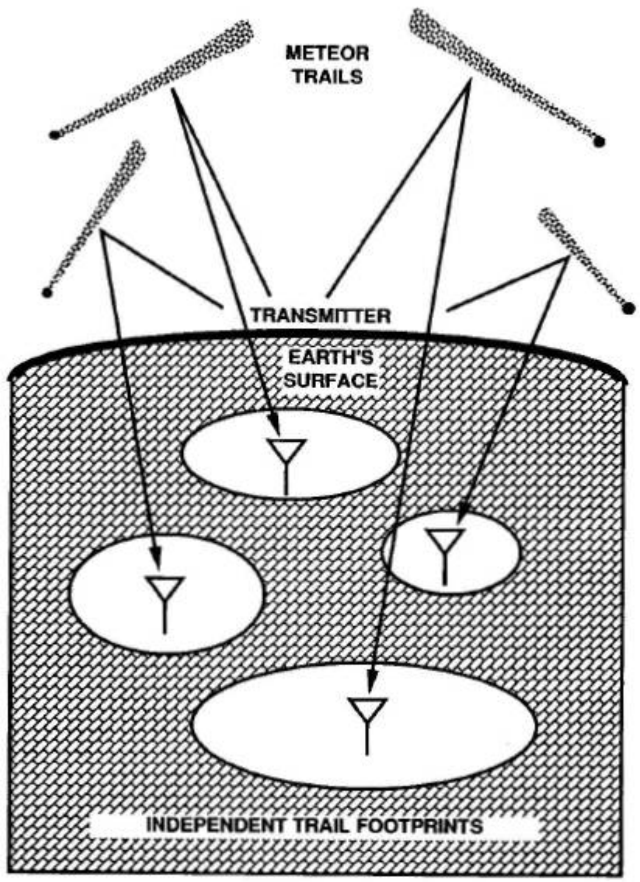
The advanced MBRS outlined in this PPT would have more advanced master base station and remote radios that are at issue in the text above and indicated by some of the drawings below.




Diurnal variation in meteor rate

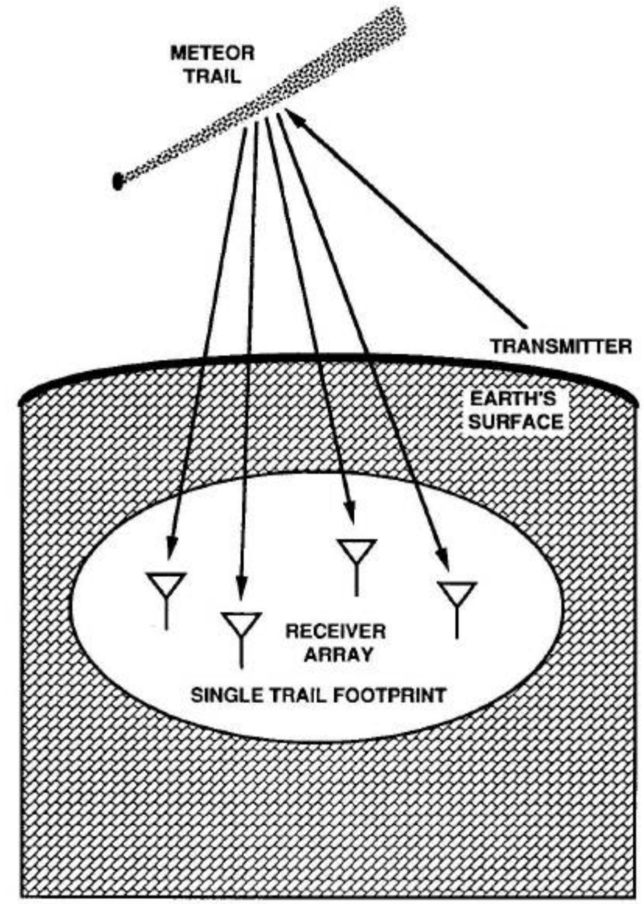



Seasonal variation in meteor rate




(a)

Spaced receivers in unique footprints




(b)

Closely spaced receivers in common footprint

Remote radio antennas is sufficiently close proximity can be linked and synchronized to improve signal to noise ratios, and to have more meteor-trail events (in '(a)' and longer time per event (in '(b)'). Each remote radio can also have phased receiver/ antennas, as explained on one slide herein from an engineer at the KAIRA radio facility.

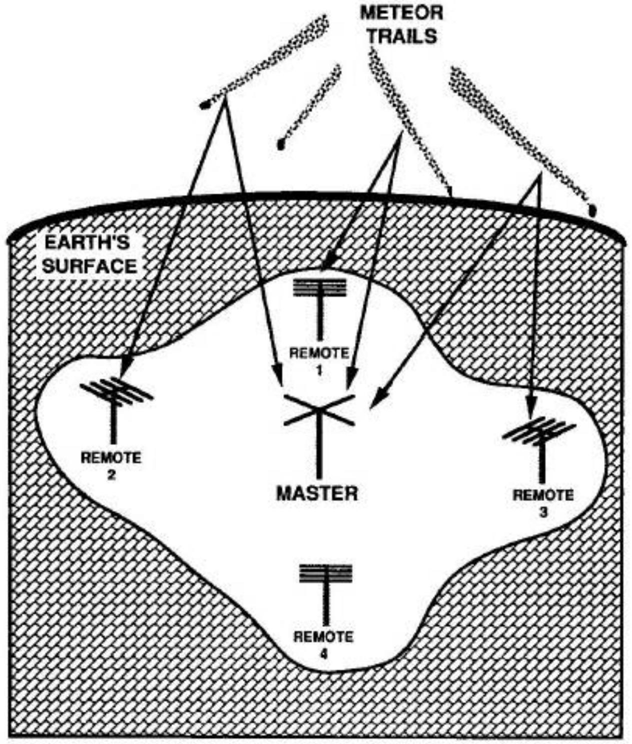



Figure 3.16 (a) Centrally-located master station

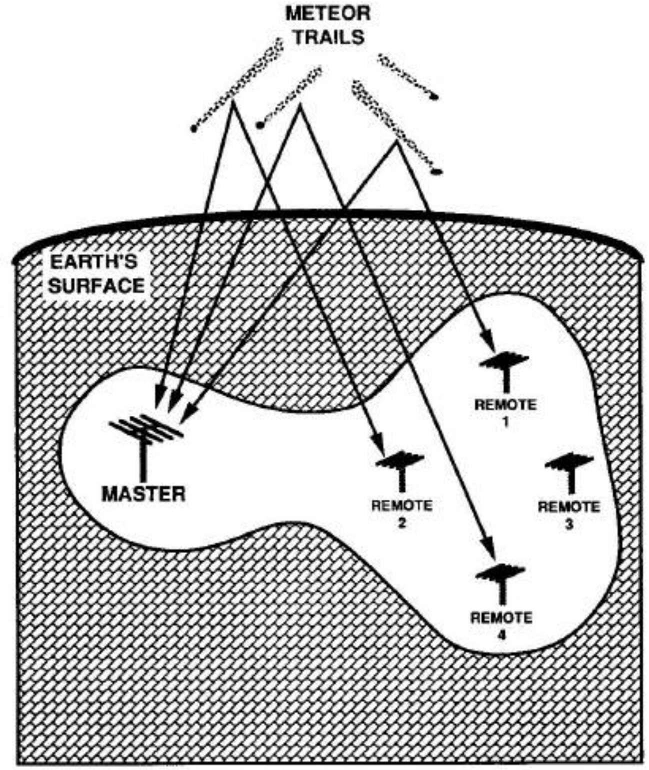
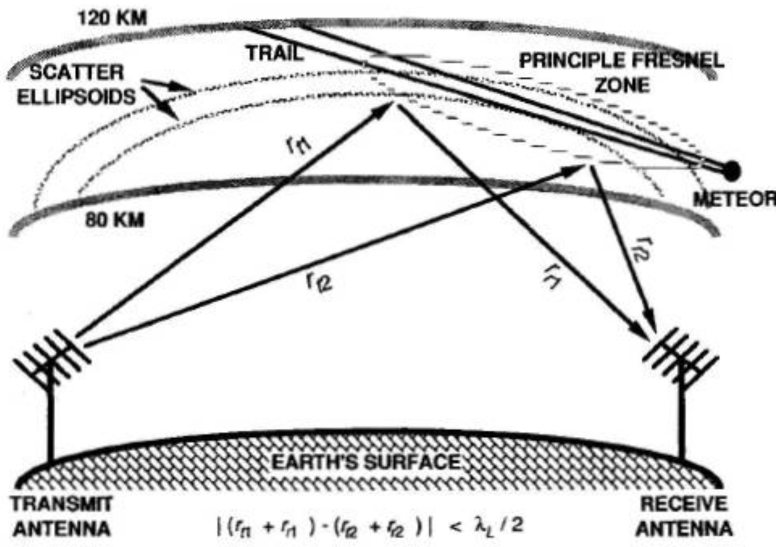


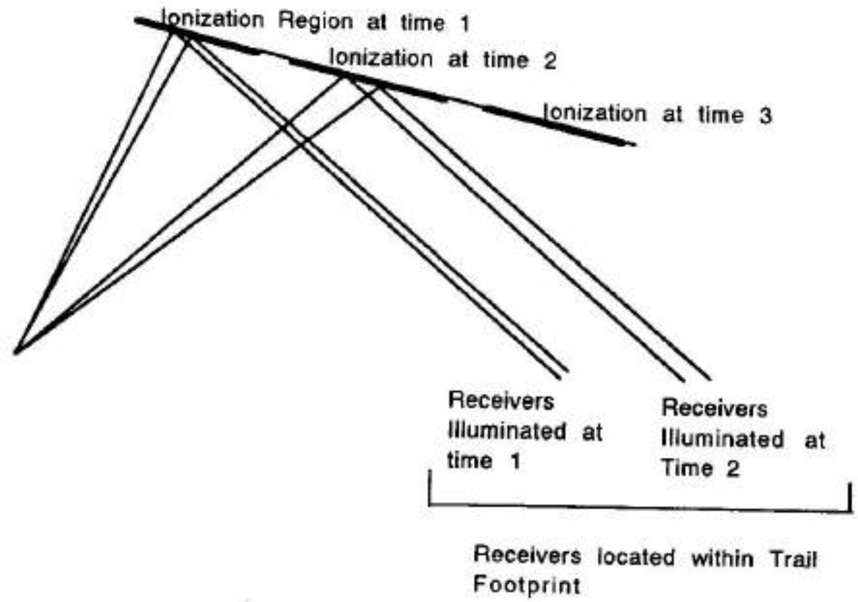

Figure 3.16 (b) Stand-off master station

Typically, for a base station well inland to cover in all or many directions. With base station antenna arrays, the array could simultaneously cover in many directions.

Typically, for a base station on or near a coastline or other territorial border to cover offshore or beyond the border (with any permissions needed by another jurisdiction).




Link geometry for meteor trail-scatter




Motion of the ground illumination region due to trail formation and decay

# Coded continuous wave meteor radar

Atmospheric Measurement Techniques Discussions
Open Access

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Received: 29 June 2015 – Accepted: 8 July 2015 – Published: 30 July 2015
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Published by Copernicus Publications on behalf of the European Geosciences Union.

## Abstract

The concept of coded continuous wave meteor radar is introduced. The radar uses a continuously transmitted pseudo-random waveform, which has several advantages: coding avoids range aliased echoes, which are often seen with commonly used pulsed specular meteor radars (SMRs); continuous transmissions maximize pulse compression gain, allowing operation with significantly lower peak transmit power; the temporal resolution can be changed after performing a measurement, as it does not depend on pulse spacing; and the low signal to noise ratio allows multiple geographically separated transmitters to be used in the same frequency band without significantly interfering with each other. The latter allows the same receiver antennas to be used to receive multiple transmitters. The principles of the signal processing are discussed, in addition to discussion of several practical ways to increase computation speed, and how to optimally detect meteor echoes. Measurements from a campaign performed with a coded continuous wave SMR are shown and compared with two standard pulsed SMR measurements.

The type of meteor radar described in this paper would be suited for use in a large scale multi-static network of meteor radar transmitters and receivers. …. For example, a continuous transmission would result in 14 dB of increased signal processing gain when compared to a pulsed system with a duty-cycle 25 of 4.4%. This additional gain can be either used to increase the fidelity of measured signals, or to reduce the peak transmit power requirements of a meteor radar system, in order to e.g., reduce the cost of a radar system….

The main advantages of a coded CW SMR are: (a) it can operate with less peak power, (b) it is suitable for a large scale multi-static radar network, (c) it does not suffer from the range-Doppler ambiguity problem, (d) there is no inherent limit to time resolution, and (e) it is less susceptible to false detections due to radio interference when compared with pulsed systems. The latter is possible since the pulse-like interferences would be 25 spread in range and Doppler in the decoding process. We would like to stress the suitability for a large scale-multi-static radar network. Not only would the low power transmitting systems with coded wave forms be more friendly with other radio users in nearby-bands, but also the

## Coded continuous wave meteor radar
(Continued)

receiving systems could be simplified, by allowing the reception of multiple transmitters on the same antenna and same frequency. The separation of the different transmitted signals would be done by knowing the code of each transmitter site.

We have shown that with modest CW system transmitting 30W average power, one can obtain results not too different from those obtained with standard pulsed transmitter. Already the existing prototype used to demonstrate the principle of coded CW SMR could be used to derive winds in the mesosphere and lower thermosphere. We expect that better results, i.e., more meteor counts, could be easily obtained by increasing the transmitter power; or by adding more transmitters and receivers to measure the same volume.

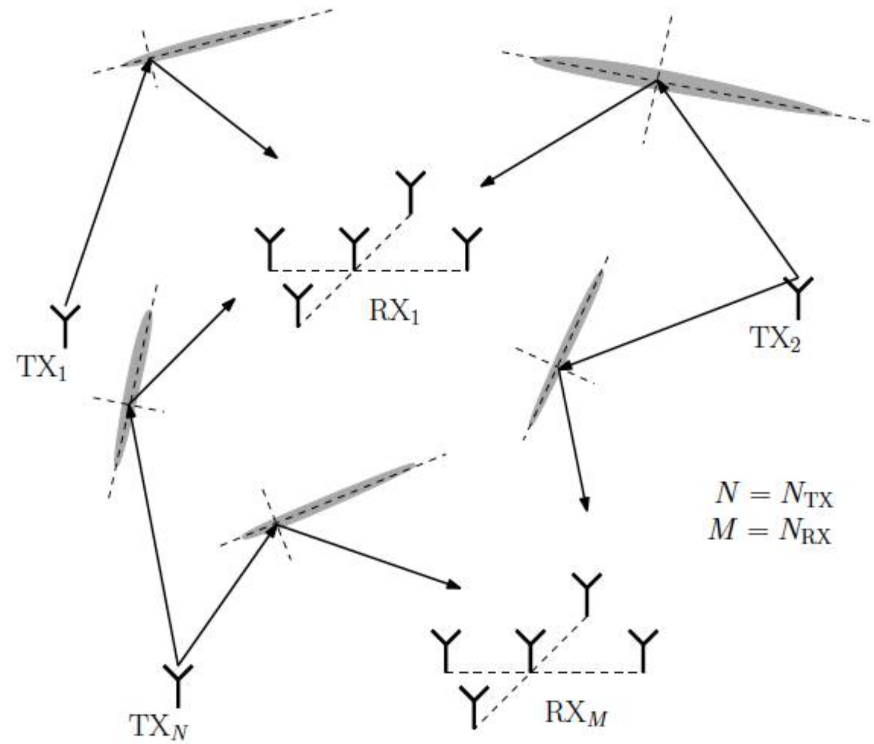


**Figure 1. A depiction of a multi-static meteor radar network with multiple transmitters and** multiple interferometric receivers. Each transmit-receiver pair observes meteors that match the specular condition, which is usually not met between two different transmit-receiver paths, and therefore to first order, each transmit-receiver path observes an independent set of meteor trails.

### Conclusions

We have described the concept of a coded CW specular meteor radar, which can be used to build a large scale multi-static network of meteor radars, in which each single frequency receiver can listen to all of the transmitters that are within vicinity. The only restriction is that the transmitter cannot be extremely close to the receiver. Our measurement campaign results indicate that the 30W coded CW meteor radar is nearly as sensitive as a standard pulsed meteor radar with 15kW of peak power and 770W of average power. …

Reference 6

# NAVAL POSTGRADUATE SCHOOL
Monterey, California

AD-A207 831

# THESIS

METEOR BURST COMMUNICATIONS FOR THE U.S. MARINE CORPS EXPEDITIONARY FORCE

by

Bernal B. Allen

March 1989

Thesis Advisor: Wilbur R. Vincent
Co-Advisor: Richard W. Adler

Comment: See underlined items. MBC can be used on aircraft. This article is about what may be called first generation MBC. We plan much more advanced MBC, using much wider channels, newer wave forms, and many other improvements, some indicated above. This more advanced MBC can be used on drones, especially larger ones, and those in wireless mesh networks that can synchronize antennas for gains.

The SNOTEL system was built for the Department of Agriculture by Western Union. It started operations in 1977 under the management of the Soil Conservation Service (SCS). SNOTEL collects information on snowpack conditions in the Rocky Mountains. The information is critical to water management planning in the West. The system covers eleven western states with 511 remote MBC stations. The remote stations are located in harsh, inaccessible terrain. They are unmanned and solar powered. The remote stations are controlled by two master stations located in Boise, Idaho and Ogden, Utah. The master stations collect data from the remotes each morning, when meteor activity is the strongest. Each remote sends data collected over the previous 24 hours in a 200 bit message. The collection process averages 20 minutes for the entire system.[Ref. 5 : p. 75-77]

There are several MBC systems operating in Alaska, two of them are the Alaska Meteor Burst Communication System (AMBCS) and the USAF's Alaska Air Command MBC system. The AMBCS, operating since 1977, is used by several government agencies. The Bureau of Land Management uses it to communicate with its survey teams operating in the Alaska wilderness. The SCS uses it for the same purposes as the SNOTEL system. The Federal Aviation Administration (FAA) sends weather information over the AMBCS and employs it during search and rescue operations in remote areas.[Ref. 5 : p. 78-79] The USAF system is used to provide backup connections among the Regional Operations Control Center (ROCC) located at Elmendorf Air Base near Anchorage, and 13 Long Range Radar (LRR) sites located throughout Alaska. Primary communications for these USAF organizations is provided by the ALASCOM, satellite system. The ALASCOM system is vulnerable to jamming, however, because "part of its footprint extends over the Soviet Union, and therefore,... could not be relied on during a US-USSR crisis."[Ref. 6 : p. 0567] The MBC system sends radar "tracks" from the LRRs to the ROCC and has demonstrated the ability to carry enough data to maintain a real time radar display [Ref. 7 : p. 46]. The USAF system includes a limited voice capability, allowing the ROCC to control interceptor aircraft over the MBC system. Routine dialog between a controller at the ROCC and an intercept pilot is limited to a small set of commands. A voice synthesizer added to the aircraft, has a coded vocabulary large enough to handle most of these routine commands. When conducting an intercept, the controller types a command code into the MBC terminal, and the pilot hears the command in English. The pilot is limited to acknowledging receipt or non-receipt of the message.[Ref. 7, 6]

Figure 23 shows information throughput achieved by two MBC systems. The first graph displays results from the BLOSSOM system operated by the Royal Aircraft Establishment of the UK. The BLOSSOM system operated on a 813 KM link from northern Scotland to southern England in March 1987. The system transmitted 600 watts on 46 MHz using antennas capable of covering both "hot spots." The BLOSSOM results shows both duty cycle and equivalent baud rate. At the point where 100% duty cycle was achieved, the throughput rate becomes the instantaneous transmission rate, i.e., 2400 Baud.[Ref. 29 ] The second graph comes from the USAF's research link in Greenland. This graph plots average throughput for the month of February in relation to the time of day. Again, a diurnal variation is present, and frequency dependency is also evident.[Ref. 15 : p. 3-12]

### . . . tactical operations area (TOA)

The MEF commander and his immediate staff may find MBC a useful way to maintain contact with the command element while airborne into the TOA. The range of MBC increases somewhat when airborne, but with a reduction in the LPI profile.

**33RD ANNUAL PRECISE TIME AND TIME INTERVAL (PTTI) SYSTEMS AND APPLICATIONS MEETING**

Editor Lee A. Breakiro. U.S. Naval Observatory Proceedings of a meeting sponsored by the U.S. Naval Observatory, the U.S. Naval Research Laboratory the NASA Jet Propulsion Laboratory, the U.S. Air Force Office of Scientific Research, the Defense Information Systems Agency, and the U.S. Coast Guard Navigation Center. **November 2001**

.....



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* ..... At present the RCM, along with the methods using transportable quantum clocks (TQC) and satellite radio navigation systems (GPS, GLONASS), ensures the comparison error of the order of tens of nanoseconds. In this case the RCM surpasses the indicated methods in such characteristics as measurement productivity, self-sufficiency, operation, efficiency, concealment, and stability to ionospheric perturbations....

| Parameters | Equipment | | | | |
|---|---|---|---|---|---|
| | METKA-1 | METKA-5...7 | METKA-4 | Phase | METKA-11 |
| Working frequency, MHz | 57.3 | | | | 45.5 |
| Impulse power, kW | 50 | 20...40 | 3 | 10 | 2...4 |
| Signal type | 6 pulses code | 16 pulses code | 4 LFM packets | PM + DFS | PM + DFS |
| Signal duration, μs | 5 | 16x2 | 4x50 | 15x26-PM, 2x500-DFS | 10x13-PM, 5x265-DFS |
| Comparison error, ns | 300 | 15...30 | 10...30 | < 1 | < 1 |
| Spectrum width, MHz | 0.4 | 1 | 2.5 | 1 | 0.2 |

LFM = linear frequency modulation; PM = phase modulation; DFS = double frequency signal.

45 MHz,
200 kHz,
<1 ns. error,
with vast of
improvement
left.

The investigation of the meteor channel precision characteristics, signal and equipment errors, and results of the comparison algorithm analysis and synthesis carried out recently have shown that the method's possibilities are far from having reached its limit.

Reference 17

*Geometry of meteor burst radio propagation. Study of Phase Non-Reciprocity of Meteor Burst Channel.*
A. V. Karpov, A. I. Sulimov, S. N. Tereshin. 2015 International Siberian Conference on Control and Communications (SIBCON)

## I. INTRODUCTION

Currently, a renewed interest in the study of problems of meteor burst communication arises. This interest is associated with the development of such advanced systems as meteor synchronization and meteor encryption key distribution. Unfortunately, non-perfect reciprocity (or simply non-reciprocity) of meteor burst channel limits a performance of these promising applications. · · ·

## VIII. CONCLUSIONS

The paper discussed the main regularities of phase non-reciprocity arising at synchronous two-way signal transmission in meteor burst communications. Time consuming and costly natural experiments on real meteor radio links of length over a 1000 *km* were replaced by computer simulation [3]. Our studies have been motivated by practical needs of the meteor synchronization systems [7-9] and systems of meteor encryption keys distribution [10-12].
· · · ·

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· · · ·

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[12] A.I. Sulimov, A.V. Karpov, "Secure key distribution based on meteor burst communications," In Proceedings of the 11th International Conference on Security and Cryptography (SECRYPT-2014) Vienna, Austria, pp. 445-450, 28-30 August 2014.

Comment: (continued from preceding page). This meteor burst (MB) encryption can be added to many electronic-information systems, *not only* to MB communications, radiolocation, and timing. This includes Intelligent Transportation Systems (ITS) including drones, smart energy grid premises systems, other smart national infrastructure, Internet connections generally, smart phones, pubic safety forces and operations, etc.

## *Information Protection Based on Nanosecond Synchronization of Time Scales in Meteor Burst Channel*

V. A. Korneev, V. V. Sidorov, and L. A. Epictetov. Kazan State University, Kazan, Russia. October 7, 2007.
Automation and Remote Control, 2008, Vol. 69, No. 6, pp. 1065–1076. c Pleiades Publishing, Ltd., 2008

INTRODUCTION

Secure encryption key dissemination required by modern methods of cryptography is one of the acute problems for today's technology. The main obstacle here is the lack of fully cryptographic means for long-distance key transfer. The importance of this problem lies in the fact that information protection is achieved by mathematical methods, based on pseudo-random sequences and random encryption keys. These methods are not proven to be unbreakable "in principle" and considering modern means of cryptanalysis aided by supercomputers, might fail given time, money or both. Guaranteed protection of information can be achieved only by frequent change of keys, what makes the key change procedure one of the most important technical problems. There are two ways of channel-based information protection currently in active development that can be used for key dissemination: quantum cryptography [1] and meteor cryptography [2, 3]. Quantum cryptography uses the uncertainty principle and currently is actively developed for application in fiberoptic channels. It is based on possibility to detect eavesdropping in such a channel. Meteor cryptography uses randomness of spatial parameters of the wave-reflecting trail together with mirroring conditions for the particular pair of communicants and good phase reciprocity of radio wave propagation. This method provides generation of "nature–supplied" encryption keys exclusively—even though radio waves are used—for two communicants located at distances up to 2000 km. Meteor cryptography claims to guarantee information protection against eavesdropping by remote cryptanalyst because in such a system the information containing the keys is [sic] not transmitted. The keys are generated in receiving antennas. . . .

. . . Meteor encryption key generation is based on nanosecond time scale synchronization and high meteor channel reciprocity [13] that makes possible two-way carrier phase time transfer measurements, with radio wave propagation parameters varying for different meteor trails in the range of 1 μs. High time scale synchronization precision allows to perform measurements of random components of current wave propagation parameters varying from trail to trail and use them as elements of key in Vernam cypher, thus providing perfect encryption according to Shannon's theorem [14]. Key generation procedure may not be performed on meteor trails used for time transfer, as time scale shift measurement gives away information about current wave propagation time in the response signal. The important question is how to distribute the rare and short intervals of channel existence to successfully and efficiently perform both high precision time transfer and generation of naturally random key sequence.

As described earlier, meteor cryptography requires that the transmitted signals contain only coordinates of the communicating points and their time scales. The keys are generated specifically for particular communicants by measuring the phases of signals transmitted in opposite directions and scattered by meteor trails with random spatial and temporal positions. These keys are visible only for communicants, they are used once and can not be predicted, bought or stolen. However this use of the meteor channel makes two working modes necessary: time transfer and key generation. In order to estimate the capacity of meteor key generation channel we first introduce a simpler problem of achieving the most of the possible key bits by measuring the full random wave propagation time with carrier frequency phase ambiguity resolved. The key generation channel capacity depends here only on the properties of meteor trails, synchronization precision and random portion of wave propagation time. The decision of switching from time-transfer mode into measurement of signal propagation time is made here by the threshold value of time-scale shift estimate error.

Comment. See following page for more articles on this meteor burst channel secure long-distance encryption that is more secure than mathematical methods. This, by itself, makes meteor burst signaling of critical importance, especially given its low cost. All modern telecom and other public and governmental electronic-information systems require highly secure encrypted systems. This is a core national security matter.


ICDO

INTERNATIONAL CIVIL DEFENCE ORGANISATION

Protection of the population, property, and the environment

Communication technologies are now a very important part in Disaster Reduction and Prevention. The seminar included some presentations made by chinese technical experts in use of Communication Technologies in Disaster Prevention and Management.

* * * *

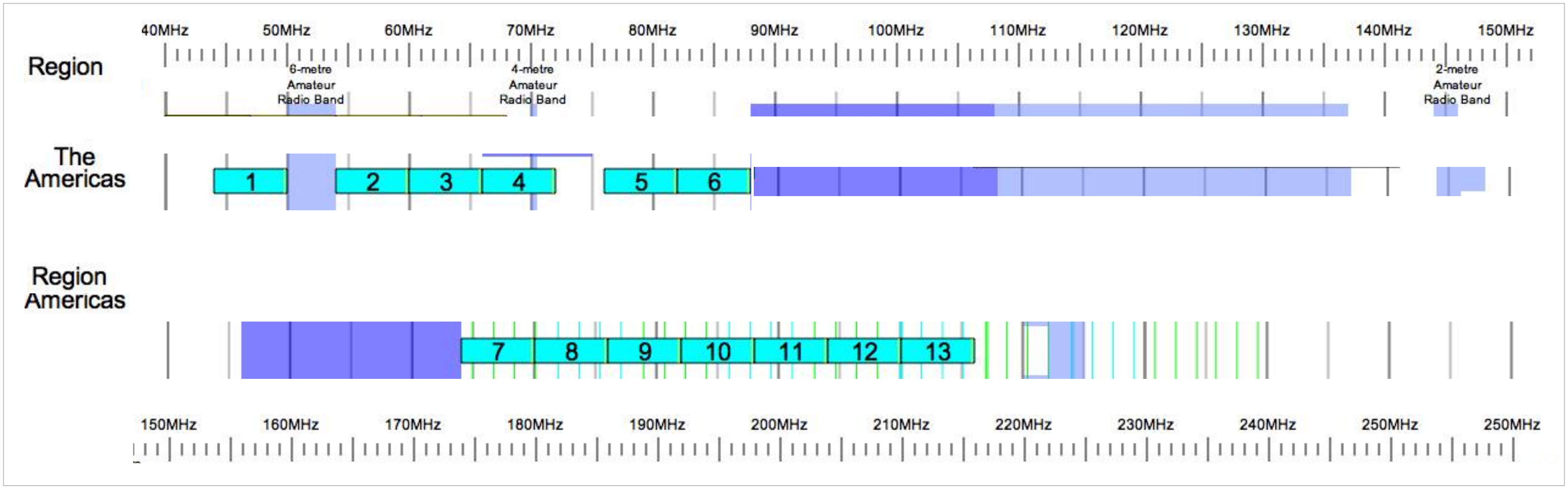
Disaster Reduction Applications of Wireless WAN based on Meteor Burst Communications – Beijing Starrycom Tech.

# 8

# Spectrum availability

(and no other spectrum users affected)

TV channel and frequencies in US. Below slides discuss use of some of these TV Channels' spectrum for MBRS, for some direct use, and some passive use.




Above charts from: https://en.wikipedia.org/wiki/Television_channel_frequencies#/media/File:VHF_Usage.svg

**VHF low-band (band I)**
**(frequencies in MHz)**

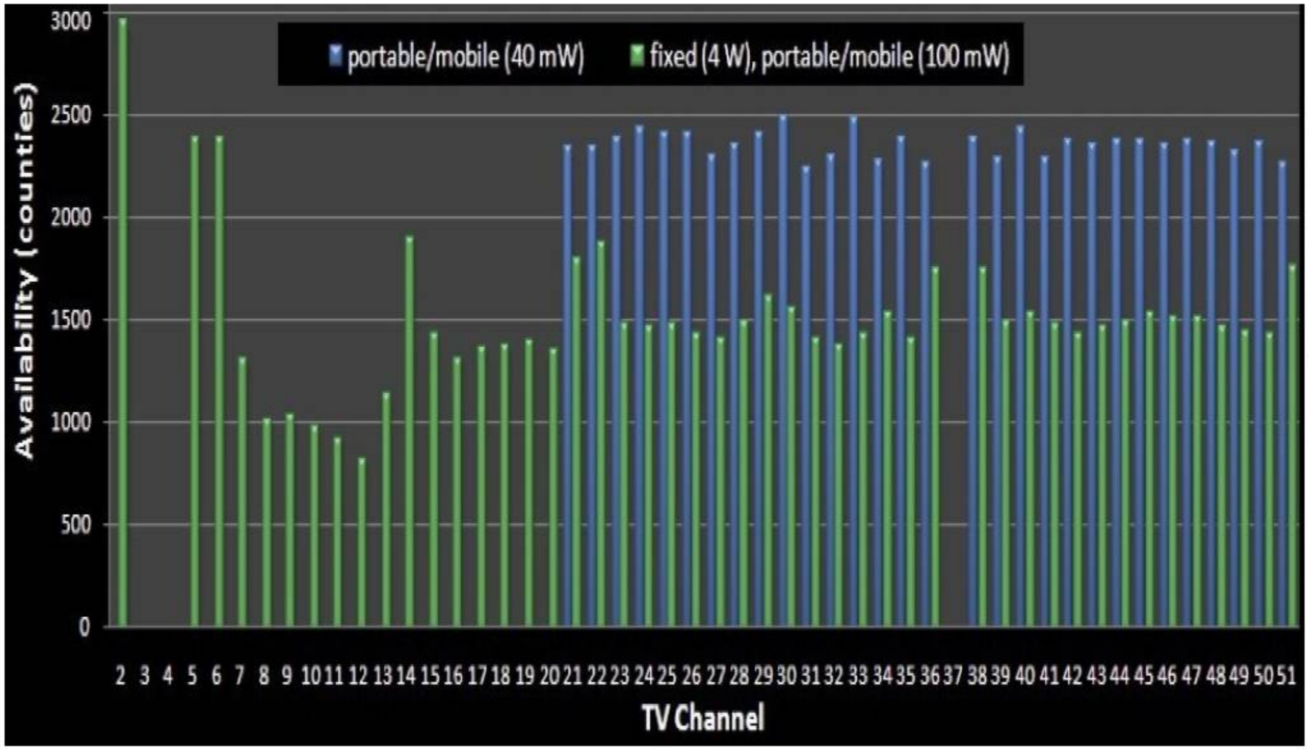
| Channel | Lower edge | Video carrier | ATSC pilot | Audio carrier | Upper edge |
|---|---|---|---|---|---|
| 2 | 54 | 55.25 | 54.31 | 59.75 | 60 |
| 3 | 60 | 61.25 | 60.31 | 65.75 | 66 |
| 4 | 66 | 67.25 | 66.31 | 71.75 | 72 |
| *(Break in band plan)* | | | | | |
| 5 | 76 | 77.25 | 76.31 | 81.75 | 82 |
| 6 | 82 | 83.25 | 82.31 | 87.75 | 88 |

**VHF high-band (band III)**
**(frequencies in MHz)**

| Channel | Lower edge | Video carrier | ATSC pilot | Audio carrier | Upper edge |
|---|---|---|---|---|---|
| 7 | 174 | 175.25 | 174.31 | 179.75 | 180 |
| 8 | 180 | 181.25 | 180.31 | 185.75 | 186 |
| 9 | 186 | 187.25 | 186.31 | 191.75 | 192 |
| 10 | 192 | 193.25 | 192.31 | 197.75 | 198 |
| 11 | 198 | 199.25 | 198.31 | 203.75 | 204 |
| 12 | 204 | 205.25 | 204.31 | 209.75 | 210 |
| 13 | 210 | 211.25 | 210.31 | 215.75 | 216 |

Above tables from: https://en.wikipedia.org/wiki/North_American_television_frequencies

Reference 14




From: *Wireless Sensor Networking over White Spaces*, *by A.* Saifullah, C. Lu at Washington University, and J. Liu, R. Chandra, S. Sankar at Microsoft Research.

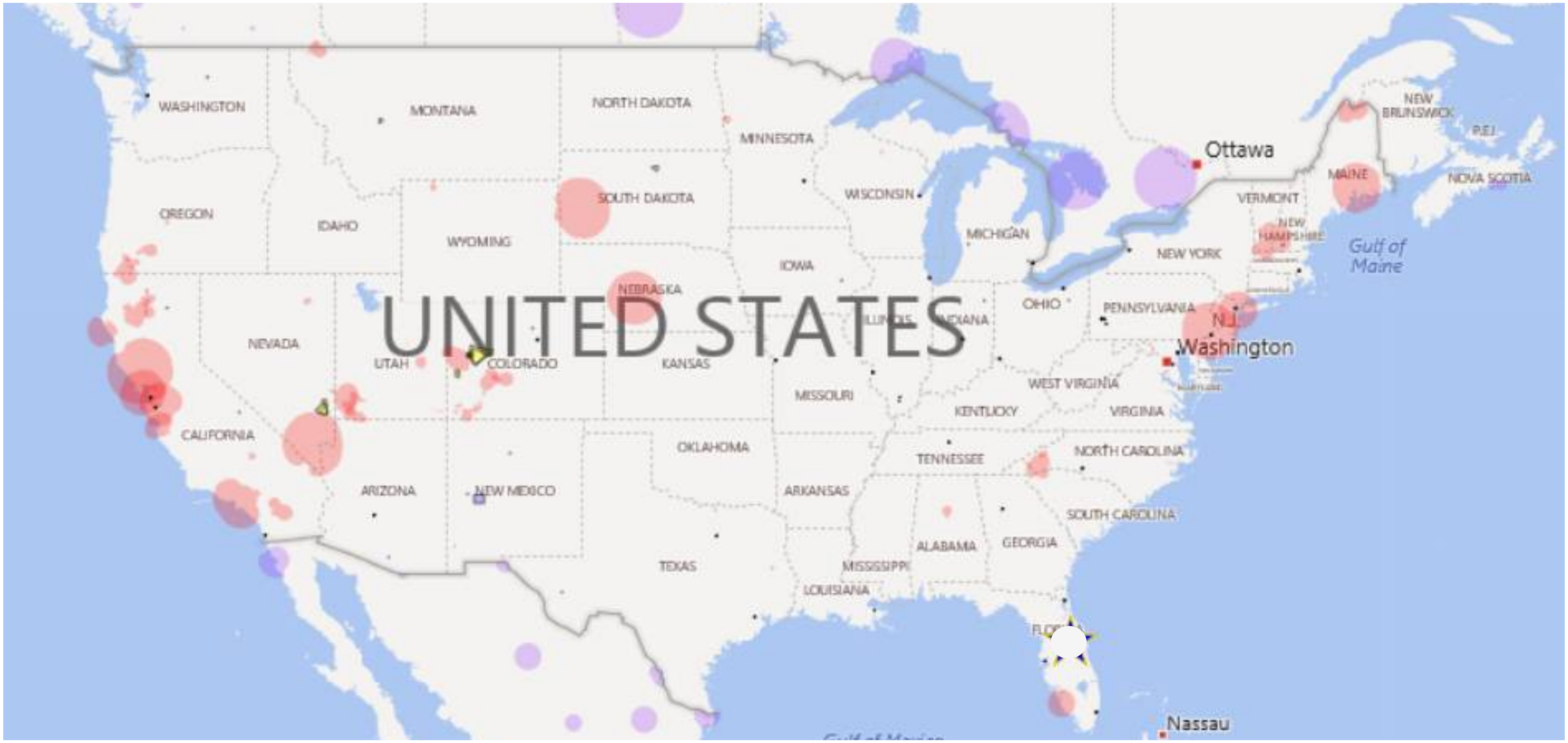
Potentially, MBRS for or in partnership with federal agencies may be able to directly use Channels 3 and 4 spectrum also, under rule waivers for good cause that I believe can easily be shown, along lines of the notes in the page above.

**Figure 1: White space channel availability in US**

## 2.1 Availability

Compared to IEEE 802.15.4 or Wi-Fi, white spaces offer a large number channels. For example, the spectrum between 512MHz and 698MHz has 30 channels (each TV channel is 6 MHz wide). The availability of white spaces depends on location. Rural (and suburban) areas, typically have more white spaces than urban areas due to lesser number of TV stations. Figure 1 shows county based availability of white space spectrum per channel from channel 2 to 51 (except 37 that is not allowed for usage) in USA, based on the statistics collected by Spectrum Bridge [9]. For a channel in x-axis, the corresponding value on y-axis indicates the number of counties among 3142 counties nationwide where the channel is available as white space. Many wireless sensor network deployments such as those for habitat monitoring [25], environmental monitoring [20], and volcano monitoring [26] are in rural areas, making them perfect users of white spaces.

This TV Channel 2 spectrum, 54-60 MHz, can be used for MBRS directly. It can also, with Channels, 3, 4, 5, and 6 (see next page) be used as a component in MBRS passive multistatic radar.

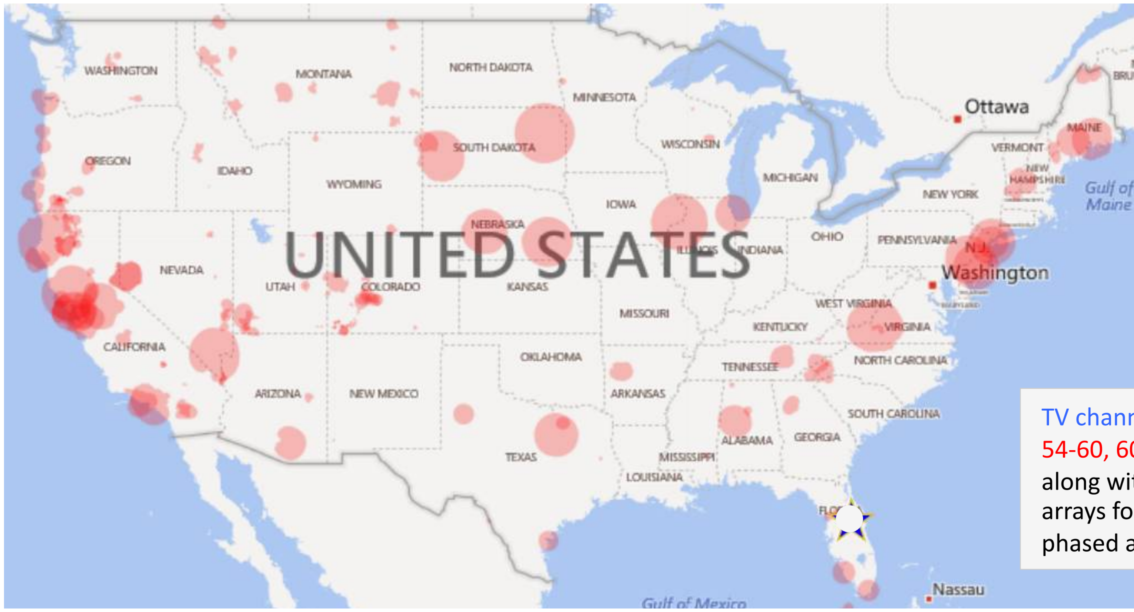



TV channel 2, from: 54-60 MHz. These signals can be received along with Part 22 low VHF VHF ~40 MHz signals in phased arrays for MBRS, including for ipPNT, pPNT, and other applications, especially in the phased arrays. See slides above. This spectrum may be used for "TV White Space" ("TVWS") fixed radios communicating with other fixed radios. FCC rule 47 CFR §15.707(b). This this regard: (1) The MBRS base stations are ***best*** located, due to MBRS's intrinsic nature, *far away* fro the urban areas, and few other areas of these TV Channel 2 stations. (2) MBRS remote fixed receivers can easily comply with TVWS rules, and will often be in remote areas. (3) The vast majority of the MBRS mobile remote receivers, and the most critical mobile applications, will be on broadcast basis, receiver only in the remote device, and there are no limitations in TVWS rules for receive-only devices. (4) MBRS use of this spectrum, in this manner, will be supplemental to dedicated exclusive spectrum as proposed herein (some federal, and some other) and any interference to the MBRS remote radios will only decrease the data rate, not the reliability or data rate for critical functions. (5) MBRS as described herein will have probably unmatched intrinsic and engineered-in means to minimize interference from any sources, and thus this "extra" data rate or capacity will be close to fully available. Thus, use of 54-60 MHz for MBRS under TVWS rules will be highly compatible with the purpose of TVWS rulemaking (to increase intelligent use of the spectrum nationwide, in non-interfering manner, including for new advanced applications, etc.), as well as fully compliant with the rules.

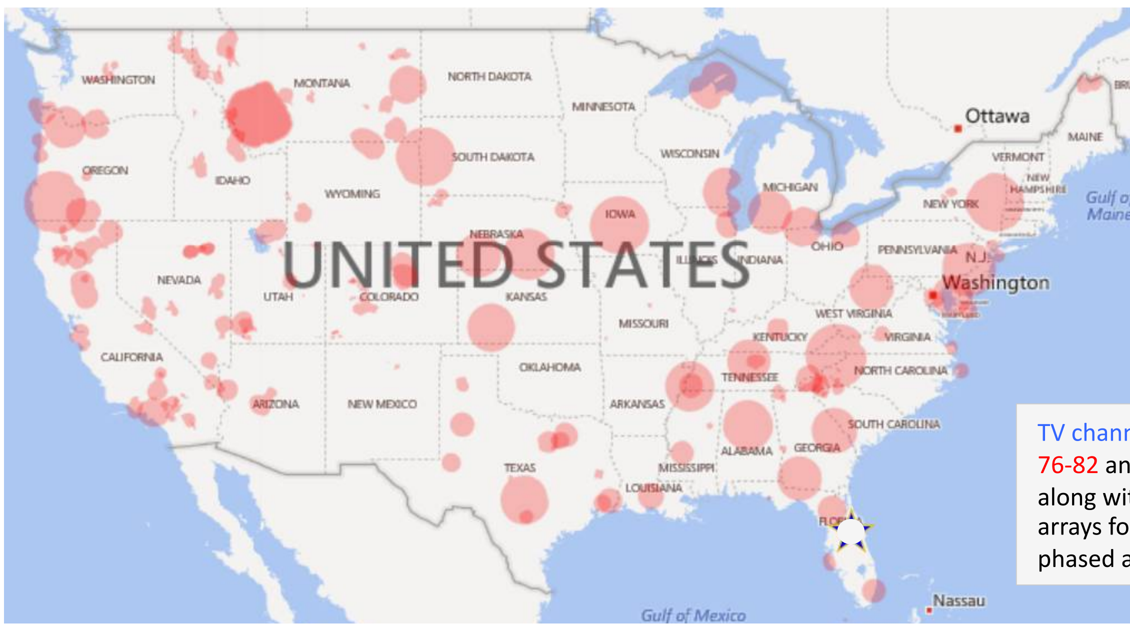
Above maps generated here: http://whitespaces.spectrumbridge.com/WhiteSpaceSearch/interactive-map.aspx (The star was embedded there by spectrum bridge not us.)

Reference 15

Maps of some VHF TV channels to show locations in US for purposes noted below.



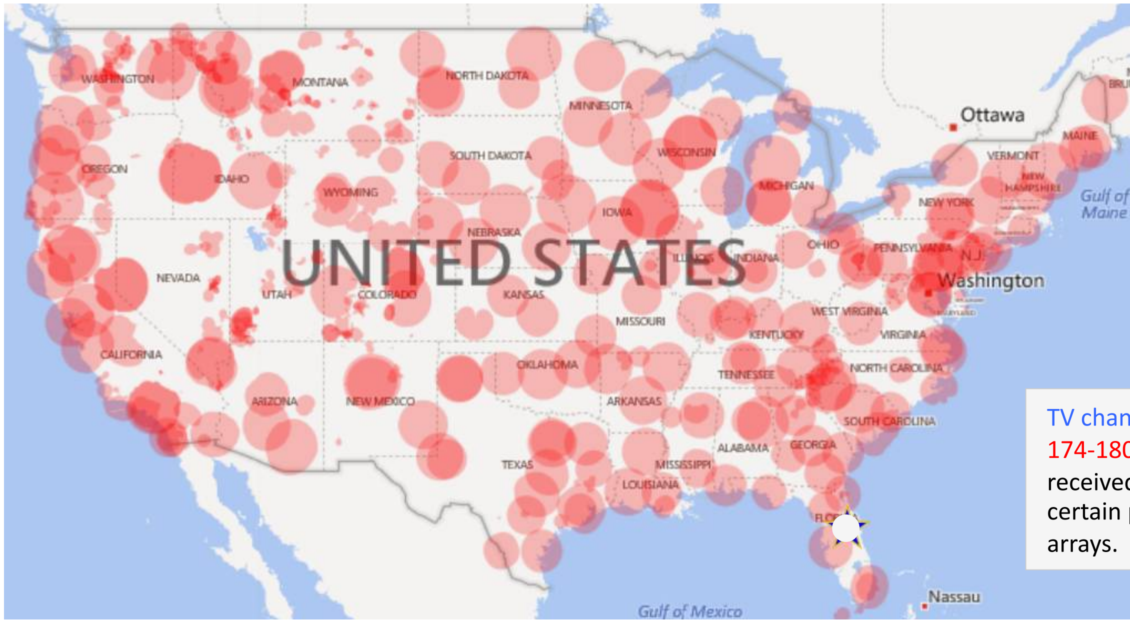

TV channel 2, 3, and 4 high power stations, from: 54-60, 60-66, and 66-72 MHz. These signals can be received along with Part 22 low VHF VHF ~40 MHz signals in phased arrays for certain pPNT and other applications, especially in the phased arrays. See slides above.



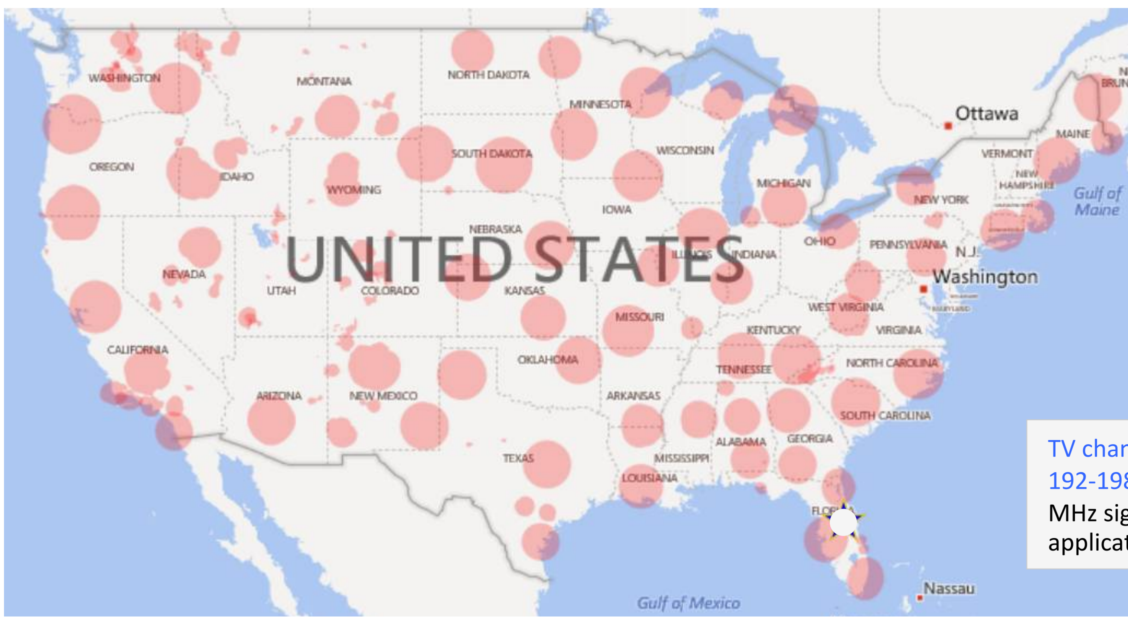

TV channel 5 and 6 high power stations, from 76-82 and 82-88 MHz. These signals can be received along with along with Part 22 low VHF ~40 MHz range signals in phased arrays for certain pPNT and other applications, especially in the phased arrays. See slides above.

Above maps generated here: http://whitespaces.spectrumbridge.com/WhiteSpaceSearch/interactive-map.aspx (The star was embedded there by spectrum bridge not us.)

Continued. Maps of some VHF TV channels to show locations in US for purposes noted below.

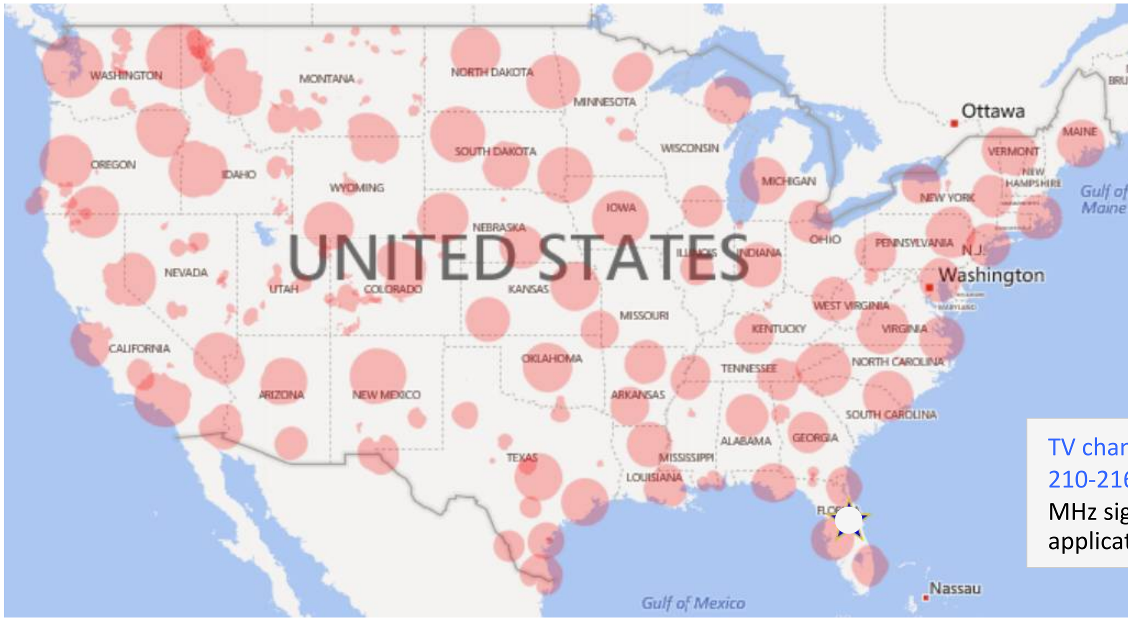



TV channel 7, 8, and 9 high power stations, from: 174-180, , 180-186, and 192-198 MHz. These signals can be received along with ~200 MHz signals in phased arrays for certain pPNT and other applications, especially in the phased arrays. See slides above.




TV channel 10 high power stations, from: 192-198 MHz. These signals can be received along with ~200 MHz signals in phased arrays for certain pPNT and other applications, especially in the phased arrays. See slides above.

Above maps generated here: http://whitespaces.spectrumbridge.com/WhiteSpaceSearch/interactive-map.aspx (The star was embedded there by spectrum bridge not us.)




Continued. Maps of some VHF TV channels to show locations in US for purposes noted below.

TV channel 13 high power stations, from: 210-216 MHz. These signals can be received along with ~200 MHz signals in phased arrays for certain pPNT and other applications, especially in the phased arrays. See slides above.

Comments.

These TV VHF channel signals--described and in part mapped in this and preceding pages-- can best be put to use as "signals of opportunity" (SsOp) for pPNT and associated critical wireless applications *by the means noted herein*, mostly above. This involves:

(1) Use of modern advanced, cost-effective, modular, SDR phased arrays to transmit and receive for GNSS-independent pPNT;

(2) These phased arrays, as shown above, that operate from about 10 to 270 MHz (they are made to do that already); and

(3) Using the TV VHF SsOp to enhance the pPNT based on skywave Meteor Burst (MB) signaling along with our dedicated spectrum in the ~40 MHz range (Part 22), but also terrestrial (and some skywave) signaling in our ~200 MHz 200 MHz, and mLMS and other 900 MHz.

(4) This cost-effective robust pPNT with dedicated-spectrum transmit and receive, and TV-channel transmissions for enhancements, will support terrestrial and airborne (including Drones) mobile-device pPNT – precise Position, Navigation and Timing-- that is essential to ubiquitous smart transport, energy, environment, public safety, defense, etc.

Above maps generated here: http://whitespaces.spectrumbridge.com/WhiteSpaceSearch/interactive-map.aspx (The star was embedded there by spectrum bridge not us.)

Note: From NTIA Assessment document.

Copy at: http://www.ntia.doc.gov/files/ntia/publications/section3a.pdf

This section provides a detailed assessment of the reallocation options for the bands under consideration. Factors such as, the Federal and non-Federal use of the band, estimated mission impact and cost to the Federal agencies, and potential benefits to the public will be addressed. A band-by-band assessment of these factors is presented and recommendations are made as to which bands will be included in the spectrum reallocation plan.

## 32-33, 34-35, 36-37, 38-39, AND 40-42 MHz BANDS

### Reallocation Considerations and Impact

The bands between 32-42 MHz are part of what is referred to as the lower Very High Frequency (VHF) spectrum. These bands are used by the Federal Government primarily for providing tactical and non-tactical communication. Because of the unique propagation characteristics in this region of the spectrum, wide area coverage is possible with a minimum number of transmitters. One type of communication that can only be supported in the lower VHF spectrum is meteor burst communications.[a] It has been determined that the 40-42 MHz band is the optimum band for meteor burst systems because there is a somewhat larger meteor scatter signal return and greater channel throughput.[4]

Re Dept. of Commerce NIST station WWV, at 20 and 25 MHz, as a MBRS pPNT potential signal of opportunity [1]
(not required, but may be useful)

See: http://www.nist.gov/pml/div688/grp40/wwv.cfm

WWV has resumed broadcasting on 25 MHz [1] on an experimental basis. The broadcast consists of the normal WWV signal heard on all other WWV frequencies, at the same level of accuracy.
* * * *
Current 25 MHz Broadcast Specifications:
Schedule: typically continuous. As an experimental broadcast, the 25 MHz signal may be interrupted or suspended without notice.   Radiated Power: 2.5 kW
* * * *
NIST radio station WWV broadcasts time and frequency information 24 hours per day, 7 days per week to millions of listeners worldwide. WWV is located in Fort Collins, Colorado, about 100 kilometers north of Denver. The broadcast information includes time..., standard time intervals, standard frequencies, UT1 time corrections, a BCD time code, geophysical alerts and marine storm warnings.
* * * *
WWV operates in the high frequency (HF) portion of the radio spectrum....radiates 10,000 W on 5, 10, and 15 MHz; and 2500 W on 2.5 and 20 MHz. [1]

See: https://en.wikipedia.org/wiki/WWV_(radio_station) [footnote added]

WWV's 20 MHz signal [1] was used for a unique purpose in 1958: to track the disintegration of Russian satellite Sputnik I after the craft's onboard electronics failed. Dr. John D. Kraus, a professor at Ohio State University, knew that a meteor entering the upper atmosphere leaves in its wake a small amount of ionized air. This air reflects a stray radio signal back to Earth, strengthening the signal at the surface for a few seconds. This effect is known as meteor scatter.[2]

See: http://radiojove.gsfc.nasa.gov/library/newsletters/latest/#6

Thomas Ashcraft reports that on November 19th, 2015 he picked up meteor scatter... reflections of transmissions from WWV at 25 MHz and 20 MHz, within range of Radio Jove equipment. Though he was not using the standard Radio Jove set this event opens up exciting possibilities for Radio Jove observers. Any one else want to try to catch a meteor trail?

----------

[1] Both 25 MHz and (with more noise mitigation issues) 20 MHz result in MB propagation as noted above.
[2] "Meteor scatter" is another term for "meteor burst" radio propagation.

Re: DOC NIST's WWVB at 60 kHz as a MBRS pPNT timing signal, in addition to MB timing

(Same applies to WWB's various HF frequency broadcasts)

See: http://www.wired.com/2013/07/wwvb-time-radio/
"The Most Important Radio Station You've Never Heard of Marks 50 Years on the Air"

Use of WWV and WWVB for the distribution of standard time (and frequency), with other methods including MBRS is discussed in various papers, sometimes in the same paper, e.g.: http://tf.boulder.nist.gov/general/pdf/1743.pdf

WWVB provides coverage of the continental US. See maps here:
http://www.ntp-time-server.com/wwvb/wwvb.html

Casio Edifice watch with WWVB signal for timing:
http://www.casio-intl.com/asia-mea/en/wat/edifice/tough_movement/

This shows very low signals, for essential data, with robust modulation, can be received even in very small portable devices with body and ground radio-signal 'clutter.' The same applies to MBRS signals at much higher range.

For additional comparison, for eLORAN at 90-110 kHz, with 30-120 dBμV/m usable signal levels, a professional grade receiver has antenna size 19 x 19 x 8 cm: see:
http://www.reelektronika.nl/images/stories/reelektronika_LORADD_SP_Specs.pdf

Also see next-generation, cell-phone size, new Loran antennas described in this paper:
http://waas.stanford.edu/papers/DeLorenzo_ILA_2009.pdf

See next page.


**North America Signal (WWVB)**

The U.S. calibration signal (60kHz) is transmitted from Fort Collins, Colorado. It is maintained by the National Institute of Standards and Technology.

**Distribution of Standard Frequency and Time Signals**

A. H. Morgan, with the National Bureau of Standards, Boulder, CO. 1967

Abstract - This paper reviews the present methods of distributing standard frequency and time signals (SFTS)....

.... A technique employed by NBS to improve the transmitted accuracy of the frequencies of WWV and WWVH was to use the received signals of WWVB (60 kHz) and WWVL (20 kHz) at these stations to remotely control them. The NBS atomic standards are located at Boulder, Colo., and the transmissions of WWVL and WWVB, which stations are located about 50 miles away, are remotely phase controlled by means of a VHF phase-lock system....

VII. PROMISING TECHNIQUES FOR FUTURE STUDY

There are several techniques for distributing SFTS which appear to be promising and should receive further study. They involve use of: 1) satellites, 2) meteor trial reflections of VHF radio signals (also called “meteor burst”),...

## A Miniaturized Loran H-field Antenna for Handheld Devices

Continued from preceding, and continued on next page.

David S. De Lorenzo, Sherman C. Lo, Morris Cohen, Jeff Chang,
Umran S. Inan, Per K. Enge (Stanford University)

Table 1. Loran H-field Antenna Evolution.

| Parameter | Gen-1 | Gen-2 | Gen-3 | Gen-4 (tbd) |
|---|---|---|---|---|
| Antenna size | 50cm | 10cm | 5cm | 2.5cm |
| Wire gage | 22 AWG | 26 AWG | 26 AWG | 26 AWG |
| # of turns | 9 | 19 | 37 | 74 |
| Inductance | 0.16 mH | 0.10 mH | 0.13 mH | 0.23 mH |
| Resistance | 1 Ω | | | |

The H-field antennas were integrated with the LNA module and line receiver support electronics as indicated in Figure 3. The grey aluminum box contains the preamplifier and filtering circuits; the red case is the line receiver [Cohen *et al.*, 2010].

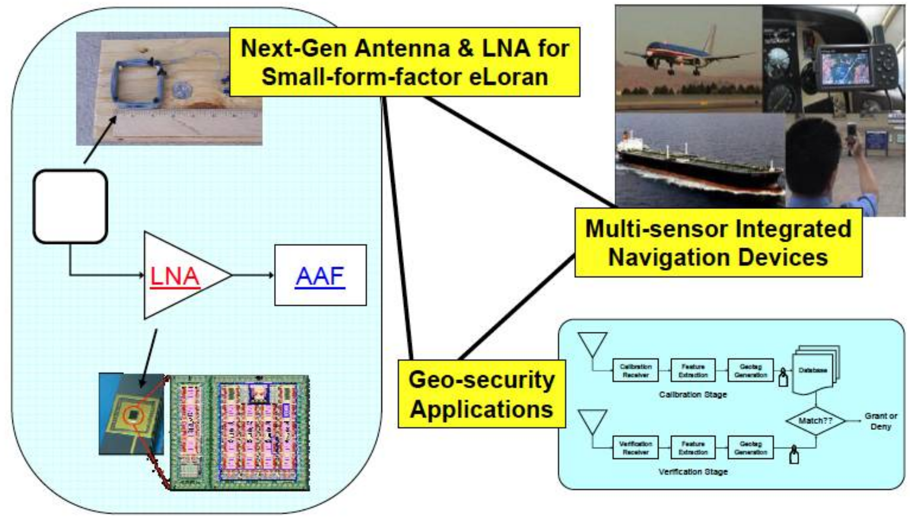



Figure 1. Enabling a Small Loran Antenna for Integrated Navigation Devices.

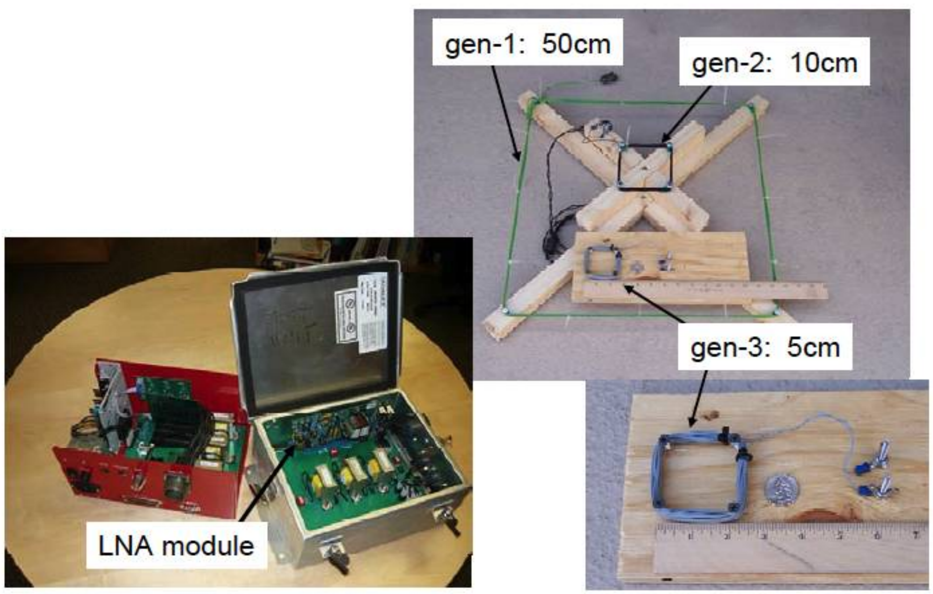



Figure 3. ELF/VLF radio reception system with various small-form-factor Loran antennas.

MBRC receive-only antennas, such as to receive broadcast-mode nRTK corrections, and ipPNT signals (GPS-independent precise Position, Navigation and Timing) can be as small, but should perform better this small, including since (1) the signals are in the ~40 MHz range, far shorter than Loran at 100 kHz; and can use (2) OAM to reduce signal to noise, (3) Optical detection of radio waves through nano-mechanical transducers (to greatly reduce internal noise), (4) base- and remote-phased arrays available in the MBRS range, and other methods (see section __ on noise reduction and use).

The below explains the noise and 'skip' problems.
As indicated on the next page, these can largely solved by the described advanced MBRC in this spectrum range.

The lower VHF band was studied by the PSWAC as a possible candidate to satisfy future public safety spectrum requirements.[12] It was determined by the PSWAC that the spectrum from 30 to 50 MHz is good for wide area coverage from mobiles to dispatch centers in open terrain. However, it was determined that portable radios operate poorly due to antenna limitations. Frequencies in this part of the radio spectrum were also found to be subject to "skip" interference between widely separated systems. The bands between 30-50 MHz are in a region of the radio spectrum where the ambient noise levels are high, particularly on highways and near industrial areas. The increased noise levels can limit the performance of a communications system by restricting the operating range, generating errors in messages and data, and in extreme cases preventing the successful operation of a receiver. Moreover, the availability of equipment in the lower VHF band is questionable. Both Ericsson and Motorola have indicated that they will no longer manufacture equipment capable of operating in the 30-50 MHz frequency range.[13] The PSWAC concluded that these technical constraints impair future use of the band to satisfy public safety spectrum requirements.[14]

Note: From NTIA Assessment document. Copy at: http://www.ntia.doc.gov/files/ntia/publications/section3a.pdf

# VHF Noise Backgrounds

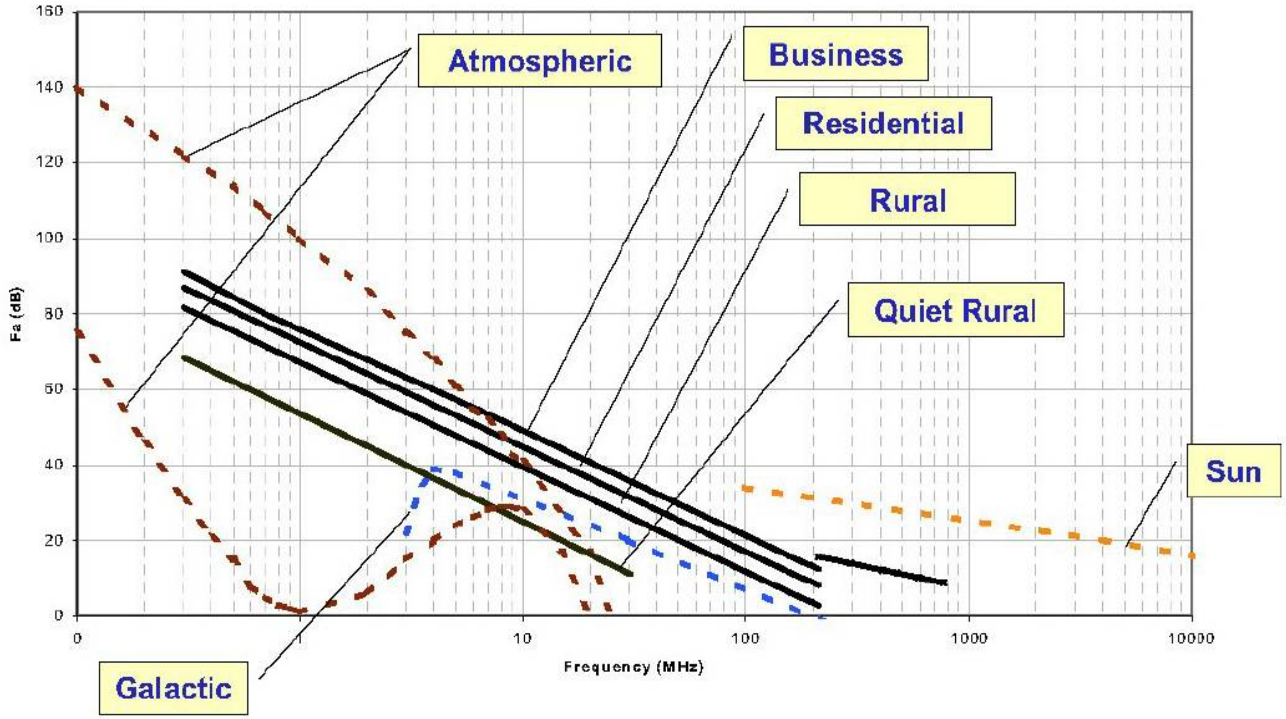



**Figure 2 Noise distribution with Frequency**

The levels in Figure 2 are taken from the ITU-R recommendation [P.372], which contains descriptions of the various types of electromagnetic noise.

Note: The above is from: "Spectral Occupancy at VHF: Implications for Cognitive Radios." Fall 2005 IEEE Vehicular Technology Conference (Dallas). By Steve Ellingson of VT, MPRG.

Most of this noise in and around ~40 MHz, for MBRS, can be eliminated by technologies presented herein including:

(1) Modern base-station phased arrays

(2) Remote-device "arrays" (multi coherent sdr, and antenna synch)

(3) Coded continuous wave meteor radar (see slide above)

(4) OAM and other means to improve corrections of polarization and vorticity distortion in signals from Ionosphere

(5) Advances in "cognitive" radio.

(6) Optical detection of radio waves through nano-mechanical transducers

(7) Ongoing advances in computer tech applied to the above and radio/ antenna tech generally

The same tech will greatly decrease RF signal levels and improve data throughput.

# Spectral Occupancy at VHF: Implications for Frequency-Agile Cognitive Radios

Steven W. Ellingson
Bradley Dept. of Electrical & Computer Engineering
Virginia Polytechnic Institute & State University



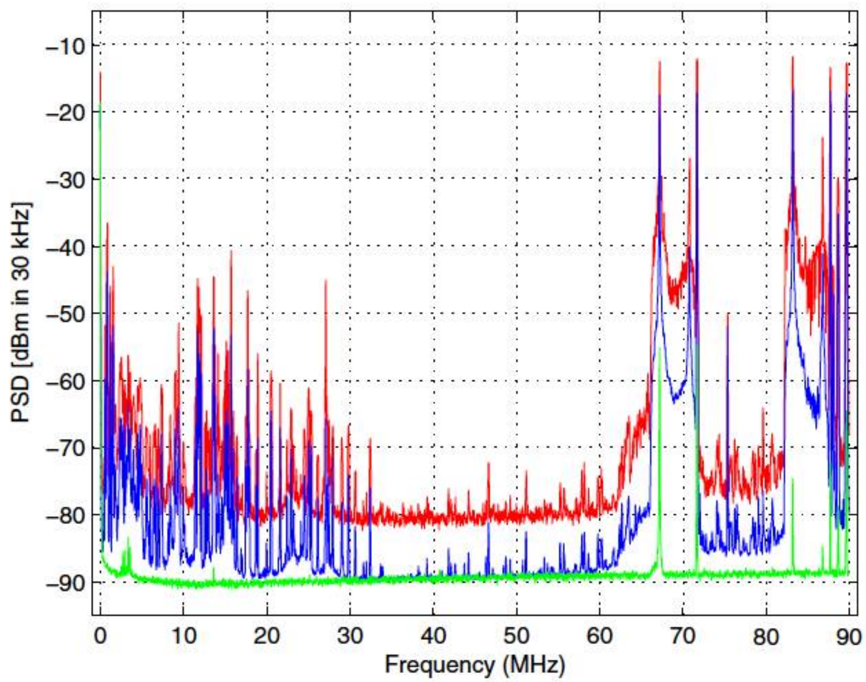



Fig. 1. Urban setting, 0–90 MHz. *Red/Top:* Max; *Blue/Middle:* Mean; *Green/Bottom:* Mean, matched load replacing antenna. (Note limited isolation in the matched load case; see text.) Resolution: 30 kHz.

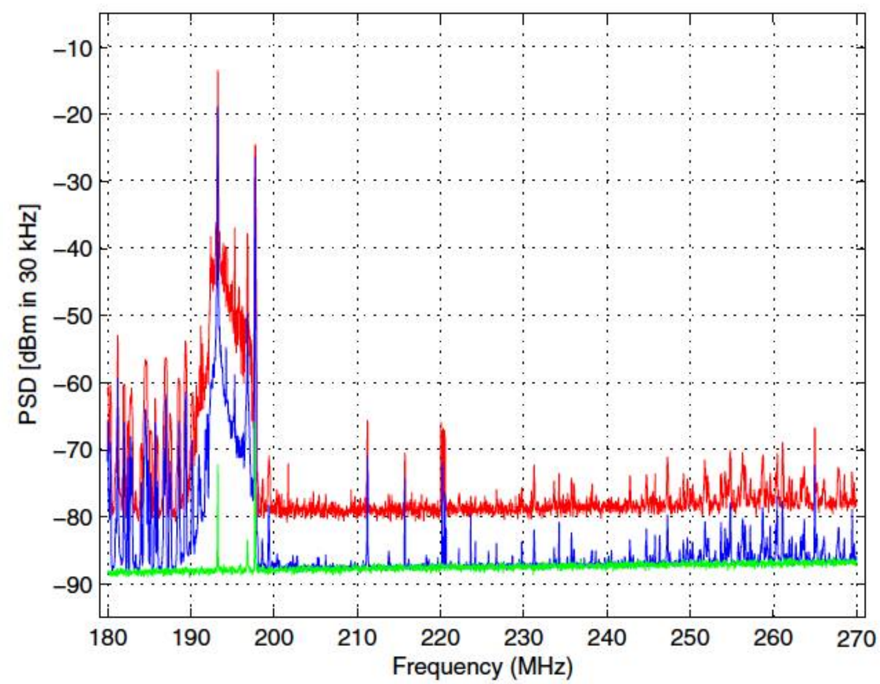



Fig. 3. Urban setting, 180–270 MHz. *Red/Top:* Max; *Blue/Middle:* Mean; *Green/Bottom:* Mean, matched load replacing antenna. Resolution: 30 kHz.

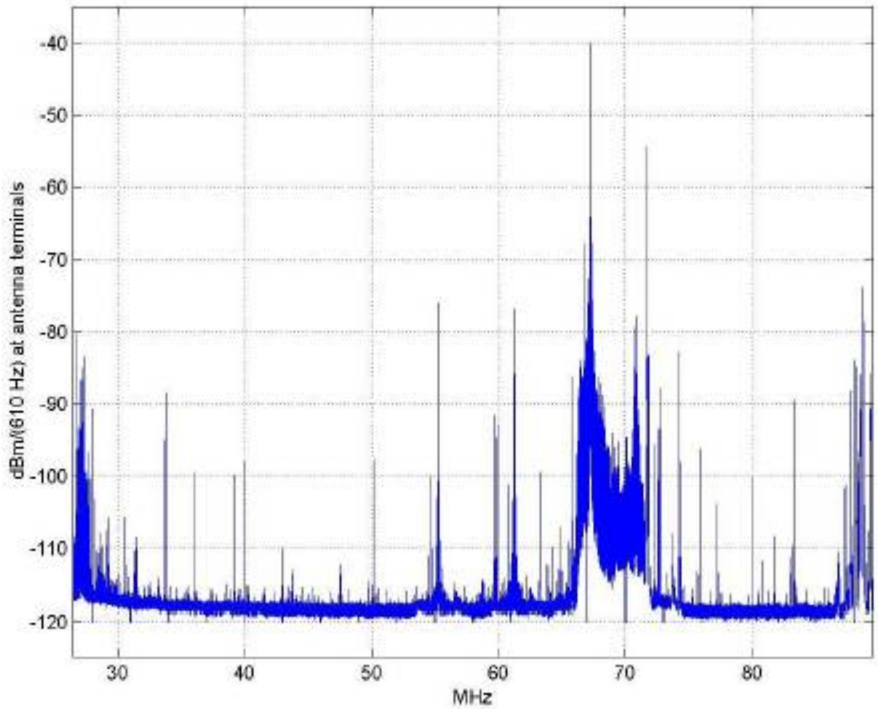



Fig. 8. Rural setting, 25–90 MHz. Mean PSD. Resolution: 610 Hz.

## IV. Implications for Cognitive Radio

It is noted that the spectral occupancy is indeed sparse in the measurements reported here. There is very little evidence of persistent activity above −87 dBm per 30 kHz in the urban setting, or above −110 dBm per 610 Hz (−93 dBm per 30 kHz) in the rural setting. In the urban setting, 30–60 MHz and 140–180 MHz were observed to be possible candidates for frequency-agile operation. In these bands, 40 and 67 openings (respectively) were found with bandwidths ranging from less than 30 kHz to greater than 3 MHz. However, it is

This paper indicates availability of large amounts of spectrum, on basis of its use in time, in both urban and rural areas. So do other spectrum use and occupancy field studies and reports from federal agencies.

Currently I cannot comment herein on some FCC licensees and licenses in this range, as indicated above.

Again, MBRS uses ~40 MHz as defined above (25-55 MHz).

## 47 CFR 15.231 - Periodic operation in the band 40.66-40.70 MHz and above 70 MHz.

**(a)** The provisions of this section are restricted to periodic operation within the band 40.66-40.70 MHz and above 70 MHz. Except as shown in paragraph (e) of this section, the intentional radiator is restricted to the transmission of a control signal such as those used with alarm systems, door openers, remote switches, etc. Continuous transmissions, voice, video and the radio control of toys are not permitted. Data is permitted to be sent with a control signal. The following conditions shall be met to comply with the provisions for this periodic operation:

**(1)** A manually operated transmitter shall employ a switch that will automatically deactivate the transmitter within not more than 5 seconds of being released.

**(2)** A transmitter activated automatically shall cease transmission within 5 seconds after activation.

**(3)** Periodic transmissions at regular predetermined intervals are not permitted. However, polling or supervision transmissions, including data, to determine system integrity of transmitters used in security or safety applications are allowed if the total duration of transmissions does not exceed more than two seconds per hour for each transmitter. There is no limit on the number of individual transmissions, provided the total transmission time does not exceed two seconds per hour.

**(4)** Intentional radiators which are employed for radio control purposes during emergencies involving fire, security, and safety of life, when activated to signal an alarm, may operate during the pendency of the alarm condition

**(5)** Transmission of set-up information for security systems may exceed the transmission duration limits in paragraphs (a)(1) and (a)(2) of this section, provided such transmissions are under the control of a professional installer and do not exceed ten seconds after a manually operated switch is released or a transmitter is activated automatically. Such set-up information may include data.

**(b)** In addition to the provisions of § 15.205, the field strength of emissions from intentional radiators operated under this section shall not exceed the following:

| Fundamental frequency (MHz) | Field strength of fundamental (microvolts/meter) | Field strength of spurious emissions (microvolts/meter) |
|---|---|---|
| 40.66-40.70 | 2,250 | 225 |
| 70-130 | 1,250 | 125 |
| 130-174 | [1] 1,250 to 3,750 | [1] 125 to 375 |
| 174-260 | 3,750 | 375 |
| 260-470 | [1] 3,750 to 12,500 | [1] 375 to 1,250 |
| Above 470 | 12,500 | 1,250 |

[1] Linear interpolations.

Note: We believe this spectrum can be used for some MBRS functions, ideally with certain waivers upon meeting rule-waiver standards, which can be met, based on use in rural areas, and drones with polarization, possibly OAM use, etc. This would be supplemental and not essential.

**(1)** The above field strength limits are specified at a distance of 3 meters. The tighter limits apply at the band edges.

**(2)** Intentional radiators operating under the provisions of this section shall demonstrate compliance with the limits on the field strength of emissions, as shown in the above table, based on the average value of the measured emissions. As an alternative, compliance with the limits in the above table may be based on the use of measurement instrumentation with a CISPR quasi-peak detector. The specific method of measurement employed shall be specified in the application for equipment authorization. If average emission measurements are employed, the provisions in § 15.205 shall be demonstrated using the measurement instrumentation specified in that section.

**(3)** The limits on the field strength of the spurious emissions in the above table are based on the fundamental frequency of the intentional radiator. Spurious emissions shall be attenuated to the average (or, alternatively, CISPR quasi-peak) limits shown in this table or to the general limits shown in § 15.209, whichever limit permits a higher field strength.

**(c)** The bandwidth of the emission shall be no wider than 0.25% of the center frequency for devices operating above 70 MHz and below 900 MHz. For devices operating above 900 MHz, the emission shall be no wider than 0.5% of the center frequency. Bandwidth is determined at the points 20 dB down from the modulated carrier.

**(d)** For devices operating within the frequency band 40.66-40.70 MHz, the bandwidth of the emission shall be confined within the band edges and the frequency tolerance of the carrier shall be ±0.01%. This frequency tolerance shall be maintained for a temperature variation of −20 degrees to 50 degrees C at normal supply voltage, and for a variation in the primary supply voltage from 85% to 115% of the rated supply voltage at a temperature of 20 degrees C. For battery operated equipment, the equipment tests shall be performed using a new battery.

**(e)** Intentional radiators may operate at a periodic rate exceeding that specified in paragraph (a) of this section and may be employed for any type of operation, including operation prohibited in paragraph (a) of this section, provided the intentional radiator complies with the provisions of paragraphs (b) through (d) of this section, except the field strength table in paragraph (b) of this section is replaced by the following:

| Fundamental frequency (MHz) | Field strength of fundamental (microvolts/meter) | Field strength of spurious emission (microvolts/meter) |
|---|---|---|
| 40.66-40.70 | 1,000 | 100 |
| 70-130 | 500 | 50 |
| 130-174 | 500 to 1,500 [1] | 50 to 150 [1] |
| 174-260 | 1,500 | 150 |
| 260-470 | 1,500 to 5,000 [1] | 150 to 500 [1] |
| Above 470 | 5,000 | 500 |

[1] Linear interpolations.

In addition, devices operated under the provisions of this paragraph shall be provided with a means for automatically limiting operation so that the duration of each transmission shall not be greater than one second and the silent period between transmissions shall be at least 30 times the duration of the transmission but in no case less than 10 seconds.

[54 FR 17714, Apr. 25, 1989; 54 FR 32340, Aug. 7, 1989, as amended at 68 FR 68546, Dec. 9, 2003; 69 FR 71383, Dec. 9, 2004]

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

* GPS- independent precise position, navigation & timing

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

References 1: Re remote radio devices: example of advancements

THE BROADCAST BRIDGE — TEST, QC & MONITORING

ACQUISITION | PRODUCTION & POST | HARDWARE INFRASTRUCTURE | SOFTWARE INFRASTRUCTURE | AUDIO | PLAYOUT, CONTRIBUTION & DISTRIBUTION

# 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.

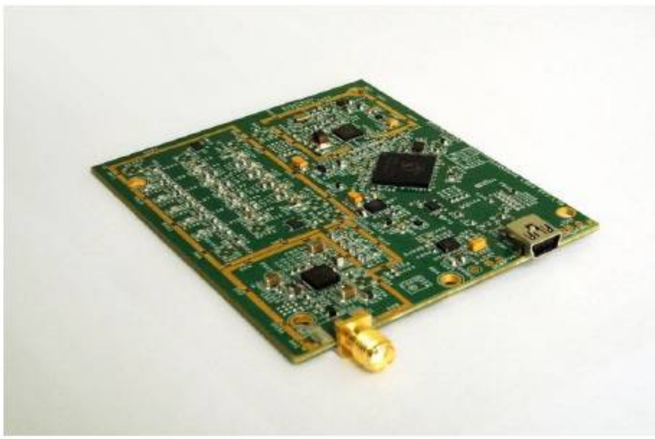
References 1: Re remote radio devices: example of advancements

# 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.

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

- 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 (2x2) 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.

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

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

# 7

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

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.

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).

# 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.

# 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.

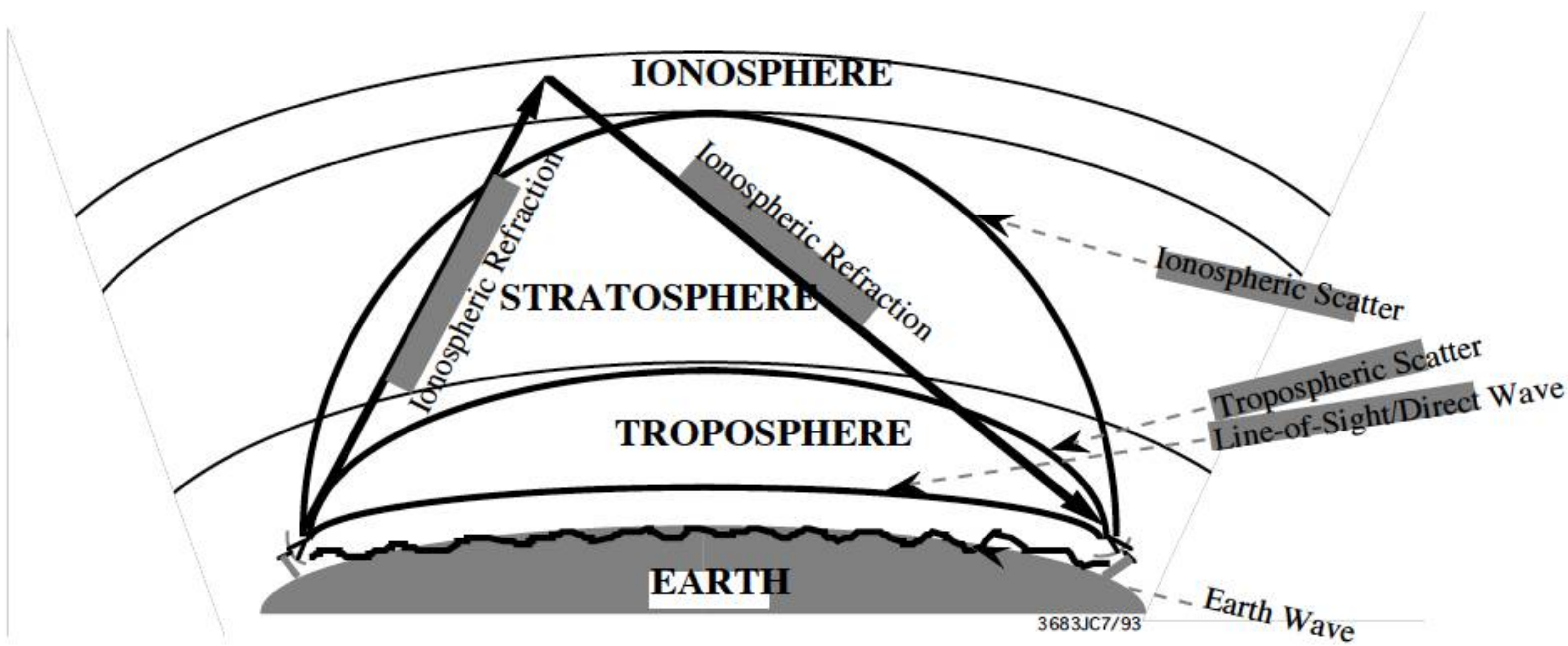
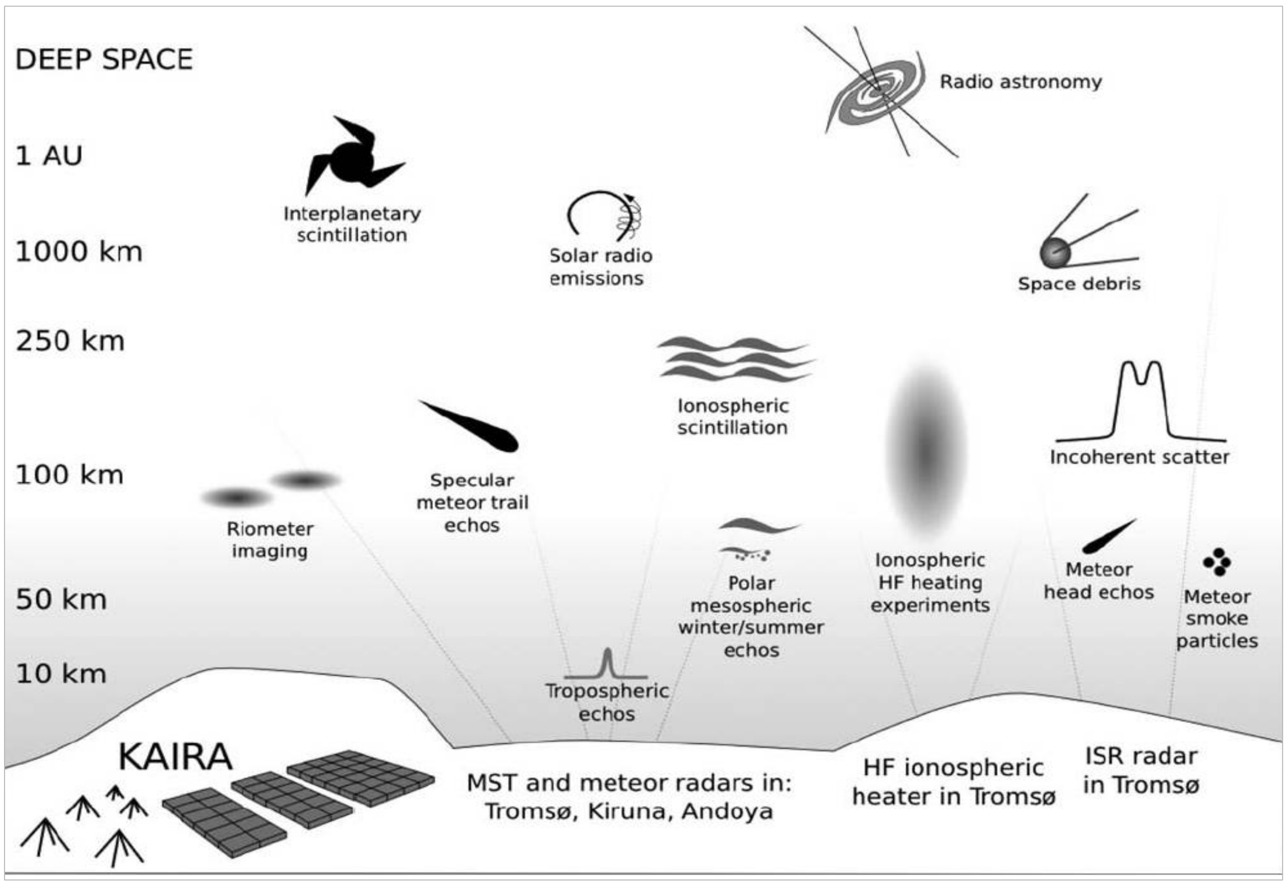



Figure 1-1. Electromagnetic Propagation

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.

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.

*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 $\mu s$ 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.

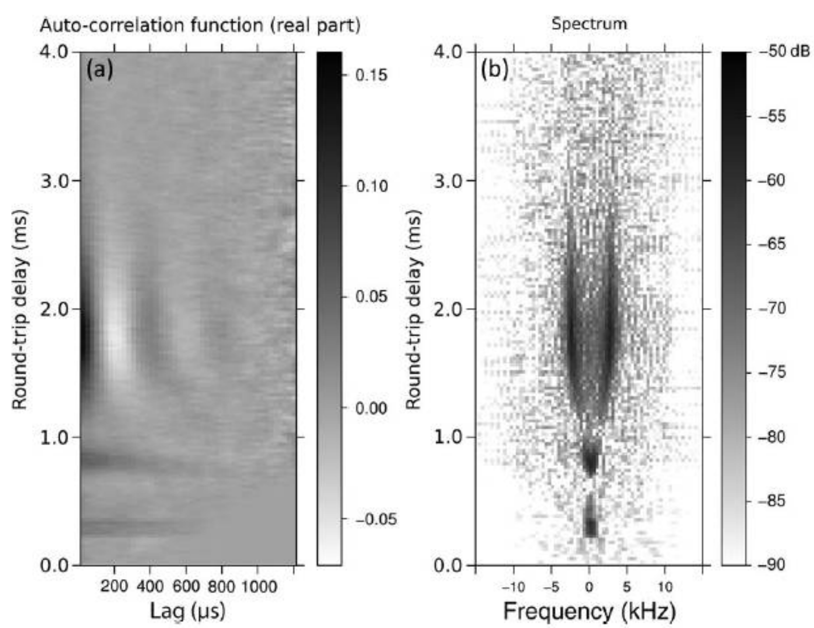



Fig. 16. First multibeam bistatic incoherent scatter radar measurement demonstrating the measurement of the incoherent scatter auto-correlation function (a), and the derived full ionospheric incoherent scatter spectrum profile (b) with respect to the transmitter frequency (224 MHz). The vertical axis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

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.

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-$\sigma$ 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.

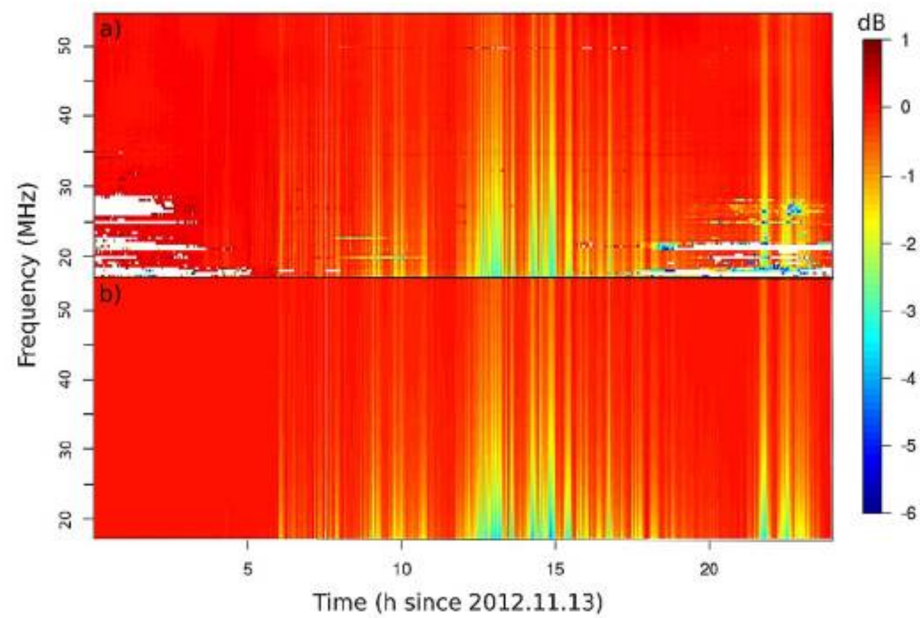



Fig. 17. Measured absorption on the vertical beam of the LBA, starting from 12 UTC on 13 November 2012. The measured absorption is shown above (a), and the forward model, corresponding to the maximum likelihood estimate of an electron density profile is shown below (b).

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.

### 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.

Rutherford Appleton Laboratory
Space Science & Technology

# LOFAR

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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.

## 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)

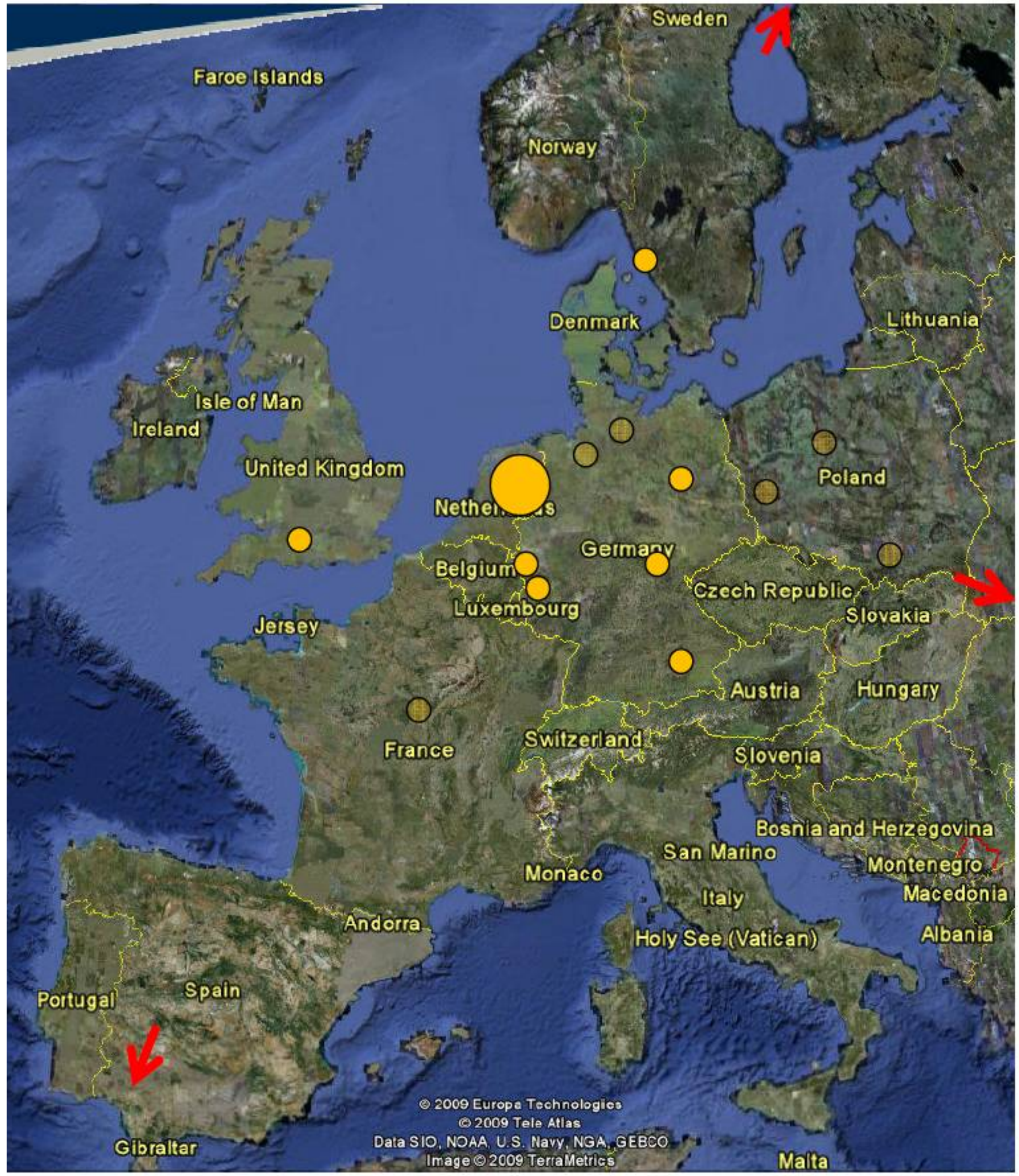
*More on this later...*

Covers most of the VHF band....

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

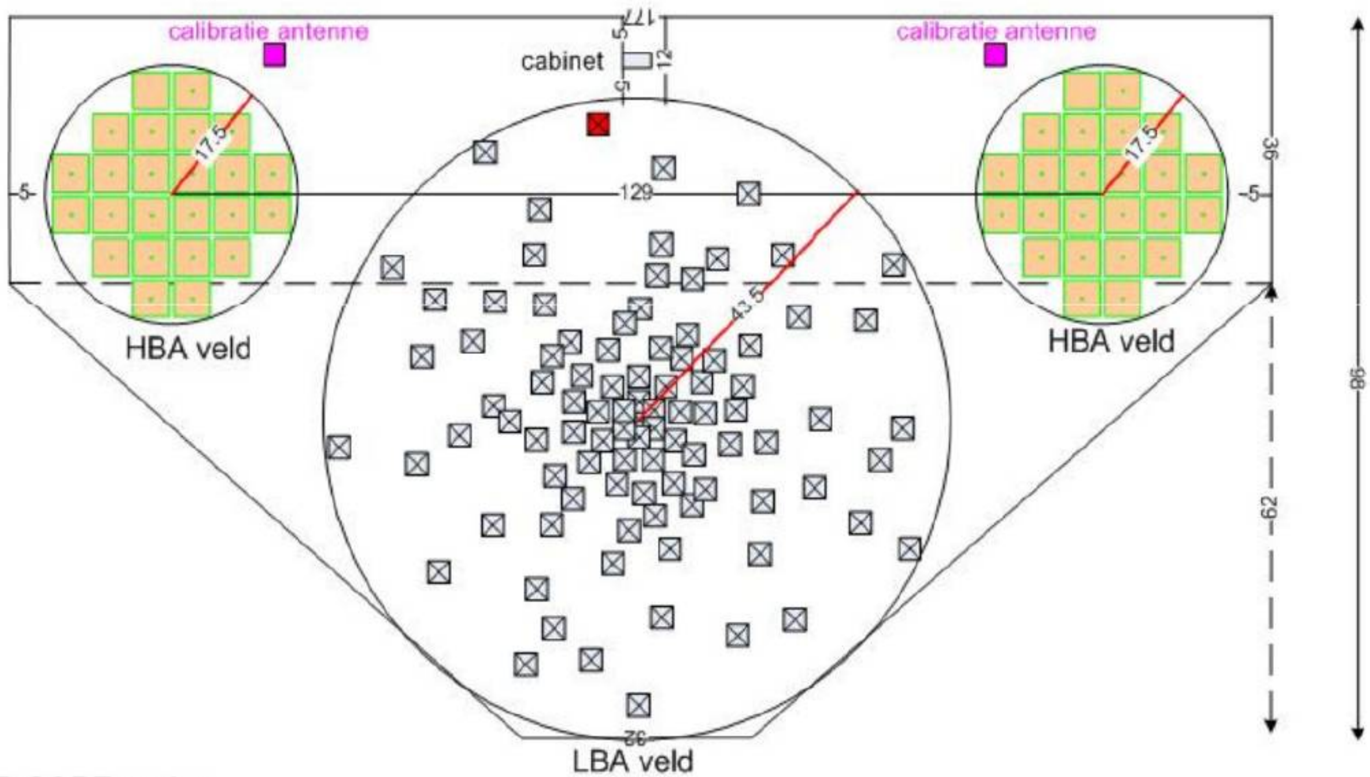
8 independent 4 MHz beams

12-bit digital output at 200 MS/s



Rutherford Appleton Laboratory
Space Science & Technology

# 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]

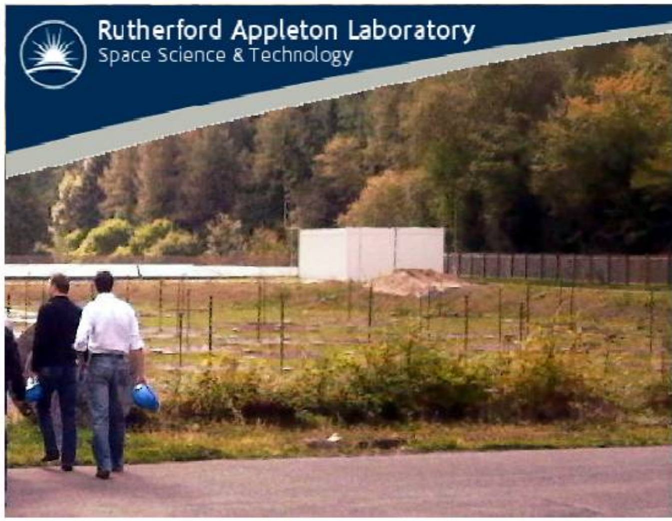
Staff effort

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.




## RF Cabinet

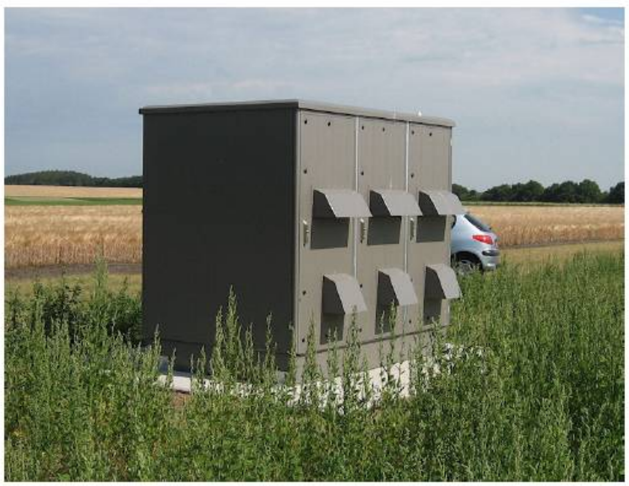
Contains:

- 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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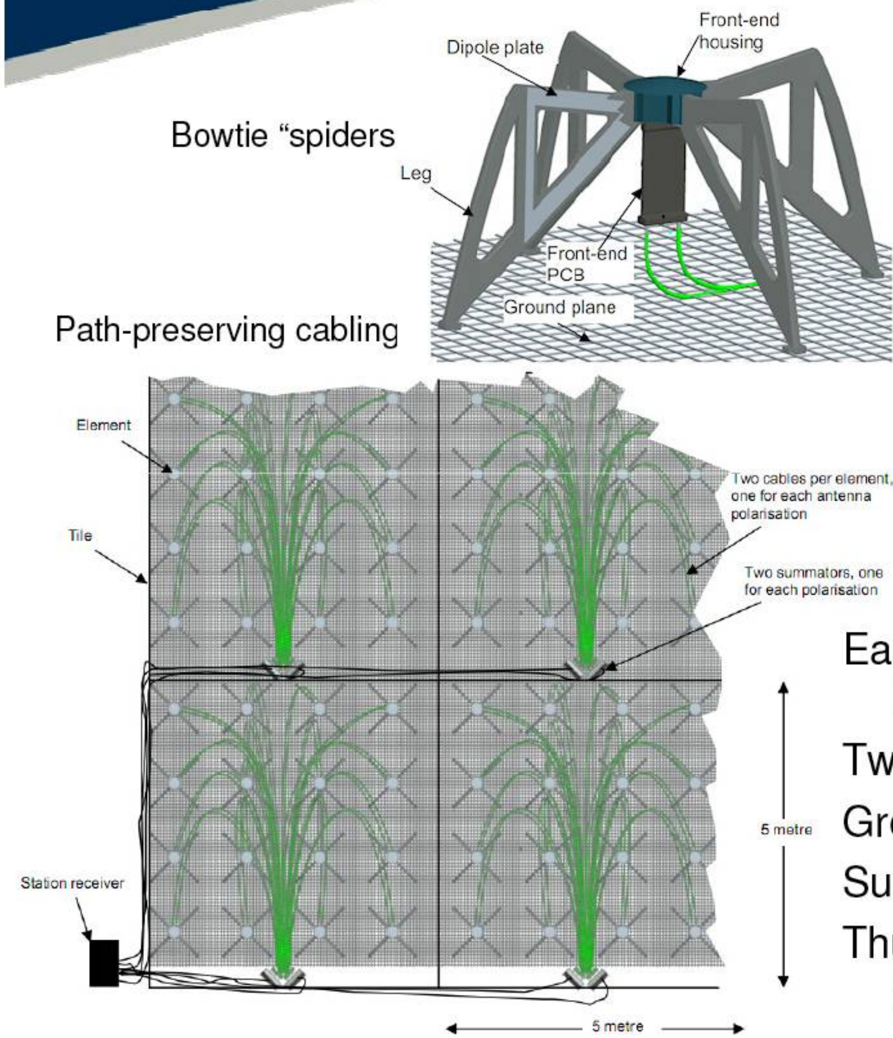
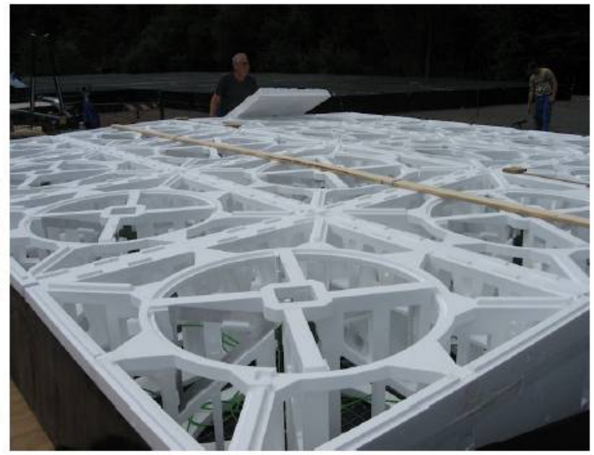
# HBA Tile Construction

Bowtie "spiders

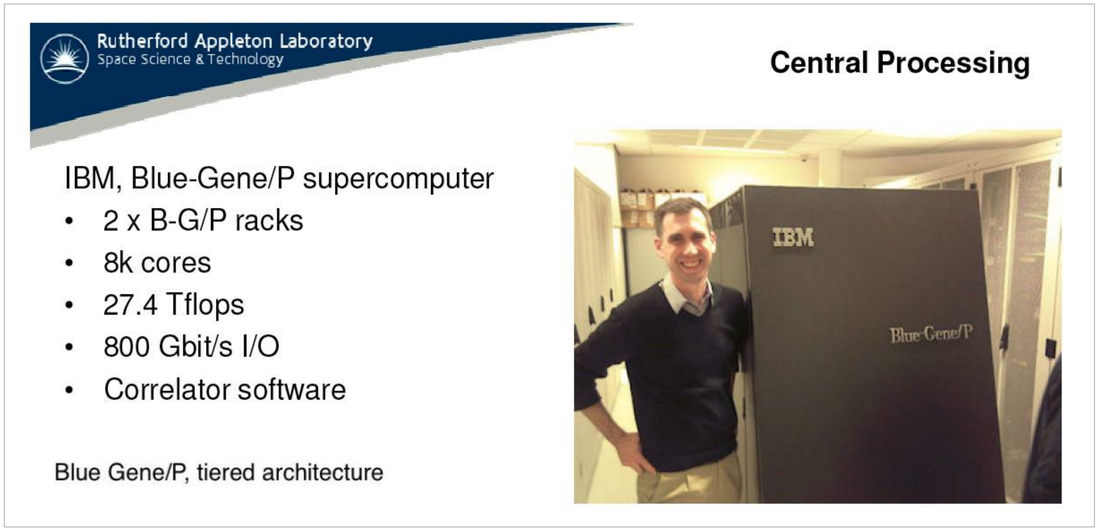
Path-preserving cabling

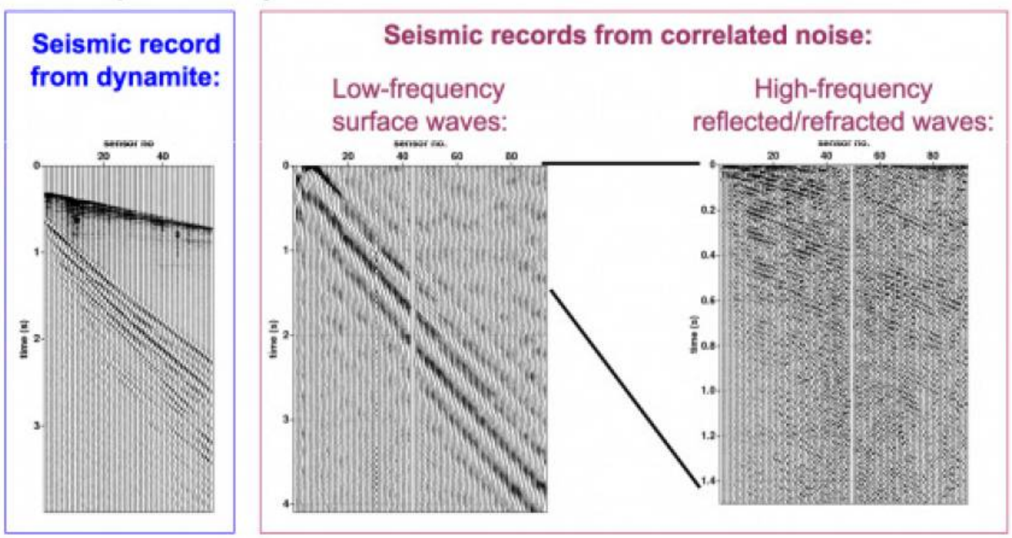


- Each tile has 4 × 4 crossed bowties
- Two linear polarisations
- Ground plane = 5 × 5cm gridsize
- Summators add at a tile-level
- Thus a tile is the smallest interferometric element

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.




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."

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.

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, ….

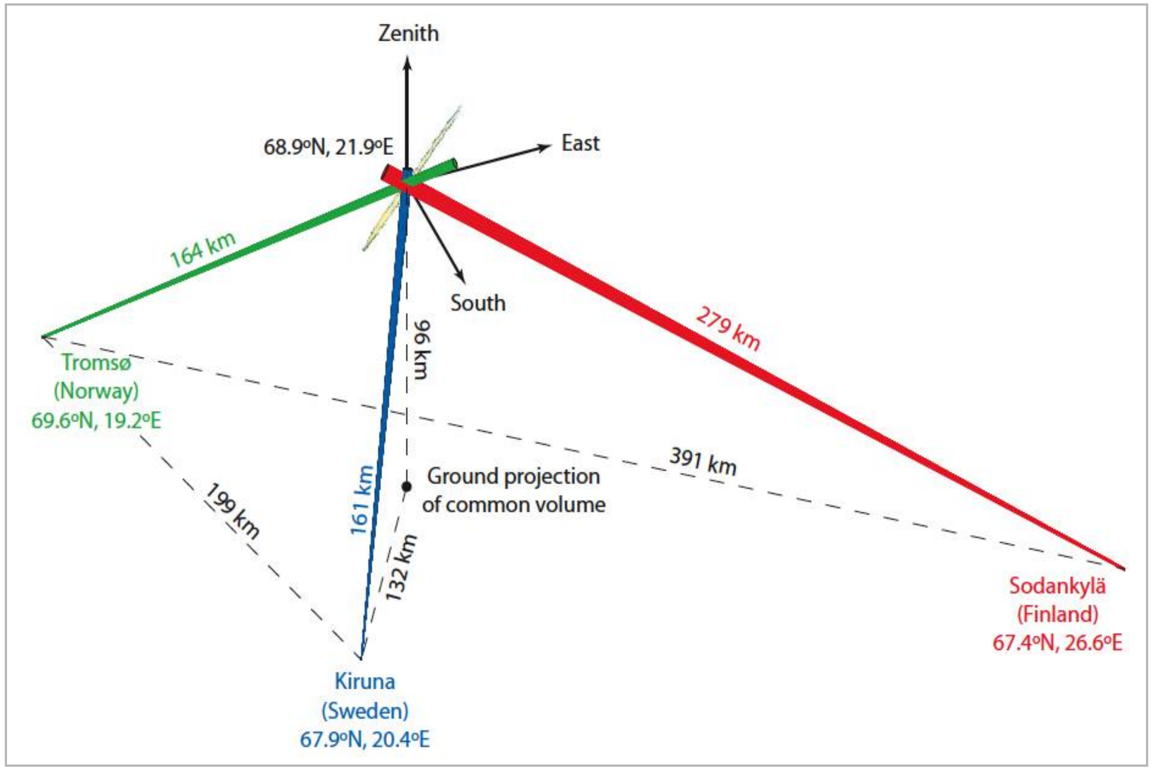
…. organising global incoherent scatter radar schools along with colleagues from the U.S…. discussions by the EU and the National Science Foundation. …

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

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.

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

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

## (AMISR)

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.

**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.

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

WSTIAC
Weapon Systems Technology Information Analysis Center
WSTIAC Quarterly
Volume 10, Number 3
2011

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.

## 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]

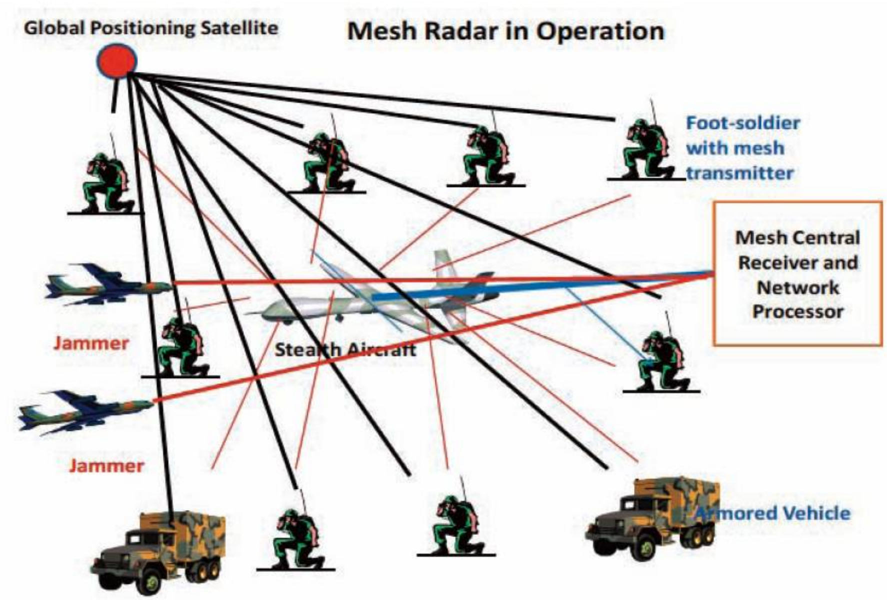



**Figure 5.** Illustration of mesh radar in operation.

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.

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.)

Reference 5

PocketSpacecraft.com

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

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.

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.

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.

Reference 8

ATDI advanced radiocommunications   Contact Us | |

## 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.

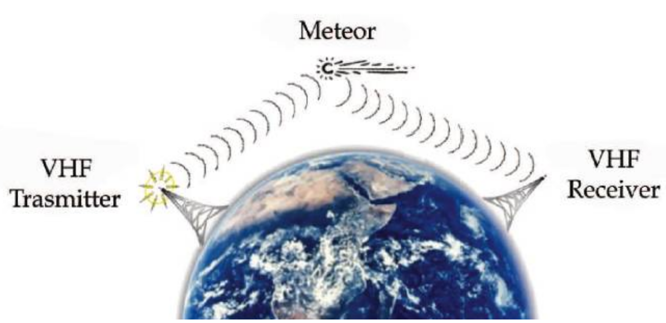
# Radar Meteor Detection: Concept, Data Acquisition and Online Triggering

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

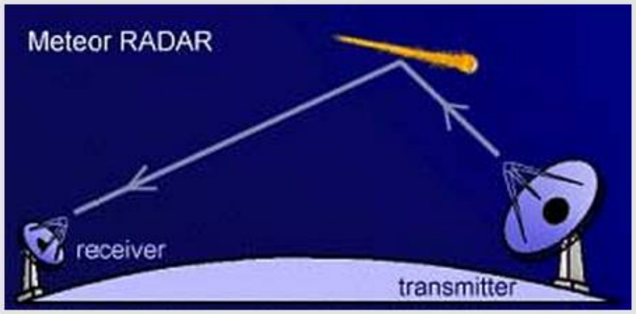
The principle of RMS detection consists in using analog TV stations, which are constantly switched on and broadcasting VHF radio waves, as transmitters of opportunity in order to build a passive bistatic radar system (Willis, 2008). The receiver station is positioned far away from the transmitter, sufficiently 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.

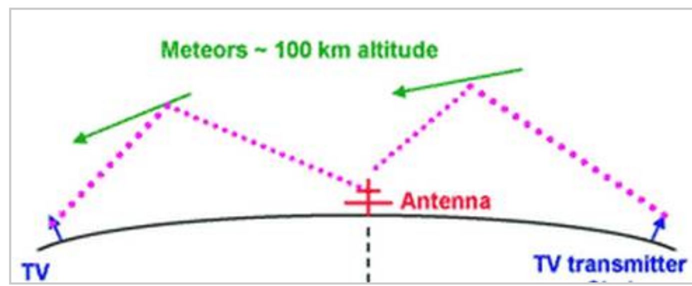
# Outreach

## 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.

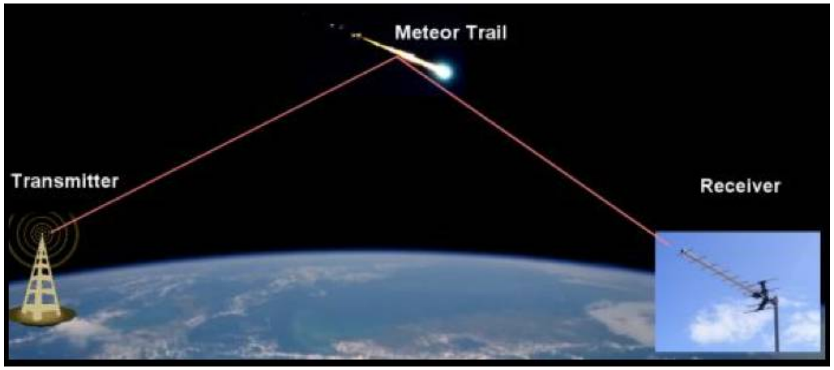
The MSFC meteor radar is tuned to 67.25 MHz, which allows the system to record echoes from an array of Channel 4 TV transmitters around the southeastern USA. All of the transmitters are over the horizon as viewed from the Marshall Space Flight Center, so it is normally impossible to detect them. The 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.

Reference 12

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



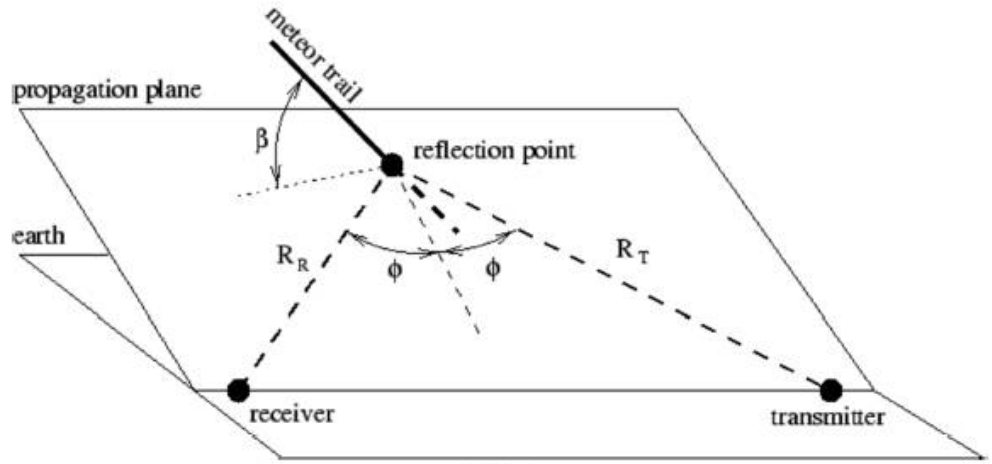




*Fig. 2*


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.

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

* Mostly Described above in the Spectrum section

## 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.


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.

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

Kunene Resources
department 13

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

# 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.

# 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

**Adrian Kotelba**
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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.

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.

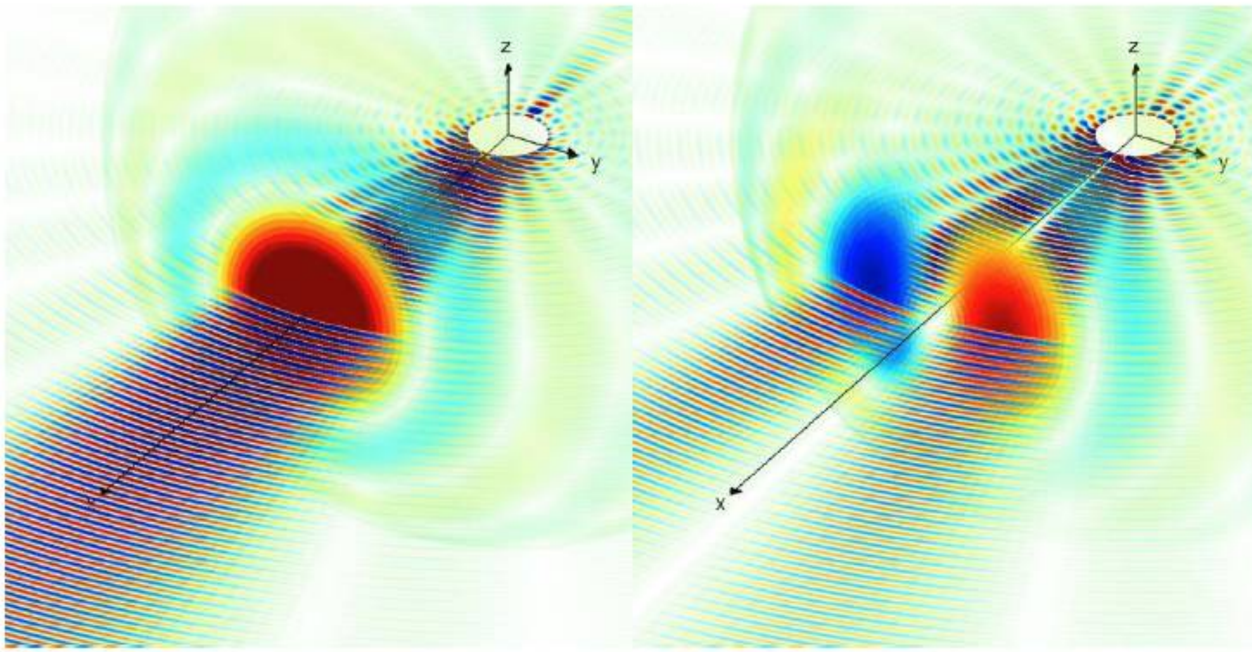



Fig. 1. Example OAM radiation modes: modes 1–2 in the left plot, modes 3–6 in the right plot.

**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.

# 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.

### 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.

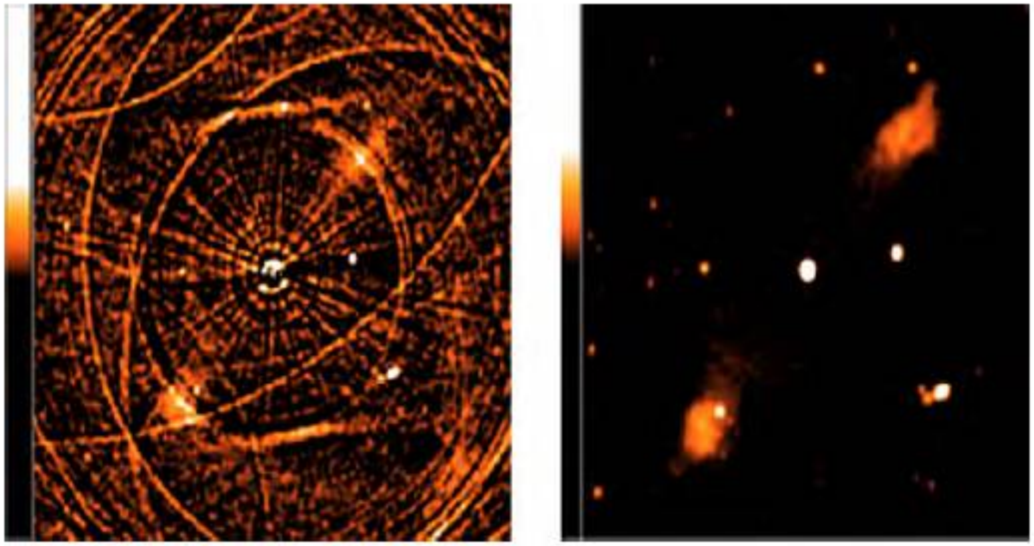


Figure 8.3:
Example of how a self-calibration procedure can reduce radio image aberrations caused by ionospheric intensity and phase distortions. The left-hand panel shows the image before the self-calibration, the right-hand panel after. The radio image data were taken at the NRLNRAO 74 MHz Very Large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

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.

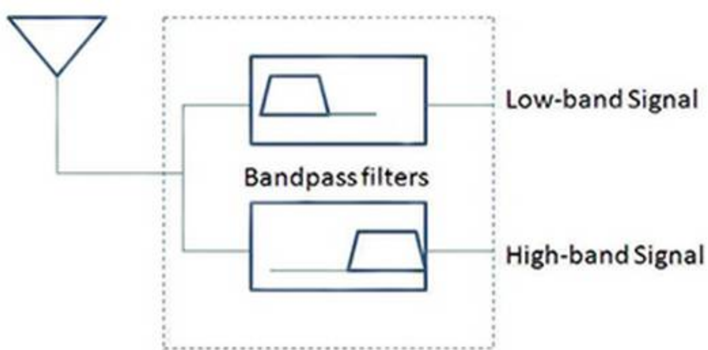



Figure 1: A basic diplexer consists of co-packaged low- and high-band bandpass filters, to split/combine two adjacent bands so they can share a single antenna.

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

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

* Mostly Described above in the Spectrum section

# 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

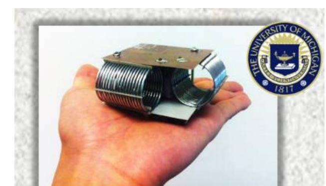
by F T Dagefu, G Verma, C R Rao, P L Yu, J R Fink, B M Sadler, and K Sarabandi, Computational & Information Sciences Directorate, ARL | K Sarabandi Dept of Electrical Engineering and Computer Science, University of Michigan

**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**



**Small Antennas for Low VHF Comms**

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

## 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 $\lambda/300$ height and $\lambda/100$ 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.