USER COLLISION IN SHARING OF ELECTROMAGNETIC SPECTRUM: Frequency Allocation, RF Interference Reduction & RF Security Threat Mitigation in Radio Propagation and Passive & Active Remote Sensing

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Abstract

[Foreword: Due to severe time constraints (10 days only) and space limitations (less than 5Mb), this review paper is still highly incomplete; and technical aspects are not treated in detail**]**

The use of passive and active UHF to VHF, microwave and millimeter wave remote sensing of the Earth's covers (lithosphere, terrestrial surface, atmosphere to ionosphere) experiences drastically increasing interference from man-made telecommunication and navigation sources for both commercial and defense applications. At the same time, the claim for ever more spectral bandwidth by the aggressive telecommunications complex is still on its steady rise, and under the un-abating pressure more bands will become designated and soon licensed by the ITU/WMO. The pertinent parts of the electromagnetic spectrum needed for remote sensing are the result of physical laws such as penetration skin depth, surface versus voluminous polarimetric vegetative scattering, atmospheric absorption bands and transmission windows, and must more seriously be treasured as a ***'fundamental natural resource'*** *for safeguarding our planet Earth. It is essential to understand why some selected regions of the spectrum are singled out, and how those must be carefully protected. Both passive and active remote sensing technologies and its specific demands will be scrutinized, whereby the current needs for sensor development in aeronomy, radio-astronomy and biomass plus meteorological remote sensing will be addressed; whereas technical aspects are not treated in detail.*

*In this presentation, an introduction to these highly important aspects of securing our current and future capabilities in terrestrial space-tele/video-communications & navigation as well as in military surveillance and environmental stress change monitoring at ground, from air and space is given. In fact, we were served an unmistakable lesson that issues of "**Environment**" and "**Security**" can no longer be intentionally separated but are intimately interrelated. The basic underlying problems causing the ever increasing number of head-on collisions for sharing into the use of the finite electromagnetic spectrum, and more regularly into the same spectral band will be analyzed in depth. Suggestions will be offered on why it is necessary to re-approach these important issues; and especially the task of completely overhauling and fundamentally restructuring frequency allocations across the entire pertinent bands, with renewed rigor and entirely novel insight. Examples will be provided on the current devastating state of misuse of*

frequency allocations, of poorly handled frequency interference reduction techniques as well as on the novel issues of security threat generation and satellite survivability, which when not properly being mitigated now, might cripple modern society unless we develop a novel holistic unified approach to these integrated issues, yet not loosing track of the associated economic constraints.

1. Introduction

The user community of the electromagnetic frequency bands within the ULF-band to the FUV-band is rapidly increasing; and the electromagnetic spectrum – **one of the most fundamental Natural Resources** - is being overtaxed in providing the required frequency band allocations. This has lead to direct confrontations between the active and the passive user groups. The active user group includes the entire terrestrial-space & mobile tele/video-communications industry, tele-navigation including the US GPS (Global Positioning System), the RF GLONASS (GLObal NAvigation Satellite System), and the EU GNSS (Global Navigation Satellite System), the defense and other active remote sensing communities, whose interests among themselves are colliding with increasing frequency because the available spectral bands are not sufficient for satisfying all needs. The passive user group consisting of aeronomy, radio-astronomy and of passive near-field sounding & far-field remote sensing are also colliding because radio-astronomy and in great parts aeronomy are directed outward toward the planetary and galactic space, whereas airborne and shuttle/satellite multi-modal passive and active remote sensing is looking down close-to-nadir on the terrestrial covers, which tends to add to the interference by the active user groups. Furthermore, the rapid increase of expanding narrow-band to ultra-wide-band mobile communication is creating havoc and an unavoidable impasse. Therefore, the entire issue of frequency allocation and radio spectral-band sharing coupled with modern advanced digital techniques, such as digital antenna bean forming, digital coding and correlation plus digital radio frequency interference reduction must be re-addressed totally. More so, after the dreadful attack on human civilization of 2001 September 11 – instigated by dangerous ill-meaning terrorist and paramilitary groups bound to destroying modern technology & civilization - has added another new inter-digitizing dimension to the issues of frequency allocation, sharing, and interference reduction, which requires the development of entirely novel techniques for mitigation of security threats to both propagation & communications as well as passive & active remote sensing of the terrestrial covers. Although hitherto remote sensing utilization of the electromagnetic spectrum was absolutely not an economically viable and less profitable venture; we request that an entirely new approach be adopted. This could mean to levy a surcharge from the commercial users for maintaining and operating the passive and active remote sensing and monitoring bands, which must be considered a justified measure in order to be able to monitor on a permanent un-interrupted time-scale the health of planet Earth; and even the *"Modern Telecommunications Complex"* cannot deny that it relies on it. We, the passive & active remote sensing community, we must consider ourselves to be therefore given the astute Professional Status with the innate responsibility of functioning as the *"Pathologists and Radiologists of the Terrestrial and also Planetary Environments",* and be entrusted to keep a watchful eye on the misuse of the "**Natural Electromagnetic Spectrum (*NES*)"**, which is indeed to be sanctified as one of the most fundamental treasures and resources of Planet Earth**.** However, propagation space pollution of ***"NES"*** is not irreversible and still today measures can be taken to reverse the trend by implementing more efficient spectrum utilization based on advances in digital communications and novel RF-EO wide-band signal conversion techniques.

2. Summary on Spectral Background Noise of Major Frequency Bands of the Natural Electromagnetic Environment, and its Man-made Noise and Interference Sources

As the electromagnetic noise levels of civilization are increasing worldwide at an alarming pace, it is essential to recover the frequency-dependent characteristics of the natural electromagnetic noise environment – *unperturbed by civilization* - across its entire spectrum and as accurate as it still can be done. The entire electromagnetic spectrum inclusive its natural background noise and resonance (eigen-frequencies) behavior must be treasured as an irreplaceable ***"fundamental natural resource***" that must be protected from erroneous anthropogenic noise and other blatant misuse. It is safe to state that there does not exist a single spectral-band within which one or the other natural geophysical phenomena within the terrestrial covers do not possess explicitly associated electromagnetic resonances as weak as those might be but essential they are for monitoring the health of planet Earth. In order to assess the deteriorating noise and RF interference on the effects on the natural unperturbed propagation space and remote sensing, it is essential to establish the average and peak natural spectral characteristics across the entire finite e-m spectrum; because every possible frequency band will soon be utilized for satisfying man's ever expanding communication needs [21].Therefore, first an identification of the major spectral regions of the electromagnetic spectrum is provided together with the currently established average natural background noise characteristics from the ULF/ELF to the IR/OPT/UV frequency bands utilized by modern technology for remote sensing the natural environment, for information transfer and navigation, and for defense and civil surveillance. The pertinent e-m and acoustic spectral bands are identified in Fig.1.

$[10^x$ Hz] x:	-6	-3	0	3	6	9	12	15	18	21	24
$[10^y$ m] y:	14	11	8	5	2	-1	-4	-7	-11	-14	-17

GLF SLF ULF ELF LF-HF UHF-EHF IR UV X-γ Cosmic

|← micro-mm → |←optical→|

← infra-sonic →| sonic |← supra-sonic →

Fig. 1: The Extra-Wide-Band Electromagnetic Spectrum with Associated Acoustic Bands

Its characteristic properties are analyzed separately in sub-sections a) to f); where currently approved averaged background noise tables and graphs are presented, and major sources of man-made noise and interference are identified in order to be able to assess the performance criteria for the truly necessary and beneficial uses of the electromagnetic environment. Later on, we need to scrutinize those users that should be excluded from free propagation-space operations, and that can be relegated to the exclusive utilization of the continental and trans-continental non-interfering optic-fiber network, which possesses excessive bandwidth, is still highly under-utilized, and eliminates unwarranted pollution of the open propagation environment.

a) Electromagnetic Background Spectra within GLF/ULF/ELF Bands: 10^{-5} to 10^{+5} Hz

The frequency-dependence of the averaged spectral characteristics over a wide frequency band of natural electromagnetic emissions within the Earth's covers and its surface are not well known

– especially not toward the lower end of the spectrum. Its determination becomes ever more hopeless with an increasing civilization unless isolated **"electromagnetic quiet zones (sites)"** are being identified and are being sanctioned as such to becoming permanent ***'World Natural***

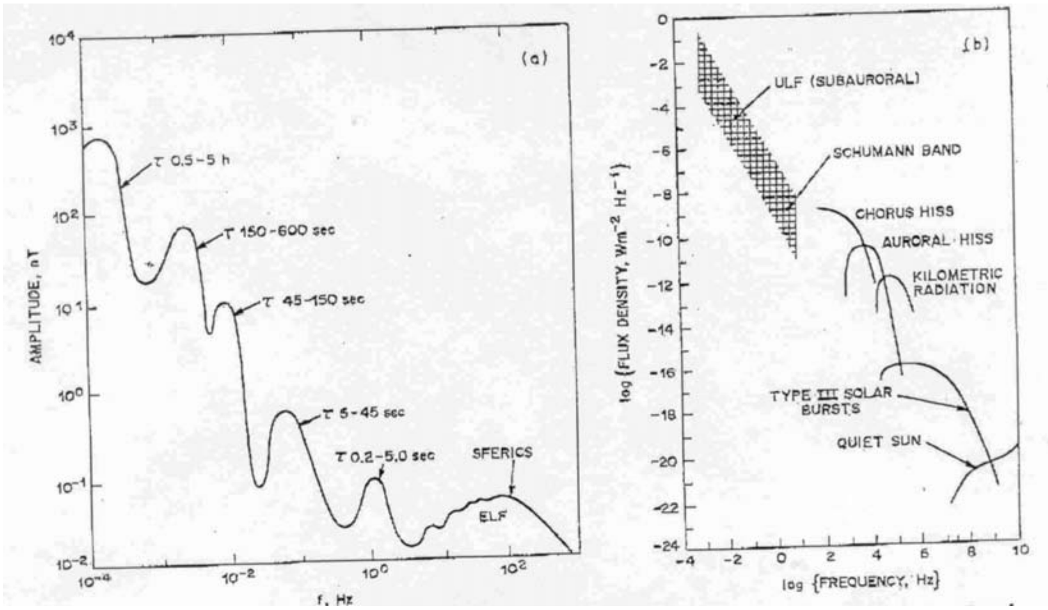


Fig. 2: Schematic magnetic field spectra, and often referred to as representative of the natural terrestrial background; (a) amplitude spectrum, and (b) power spectrum (copied from Lanzerotti et al, GRS.17(10): 1593 – 1596, Nov. 1990 – by permission of authors) [102]

Heritage Electromagnetic Ground-truthing Quiet Sites' by the United Nations. Aeronomists have sought for and identified a few isolated *"electromagnetically quiet sites*" such as the

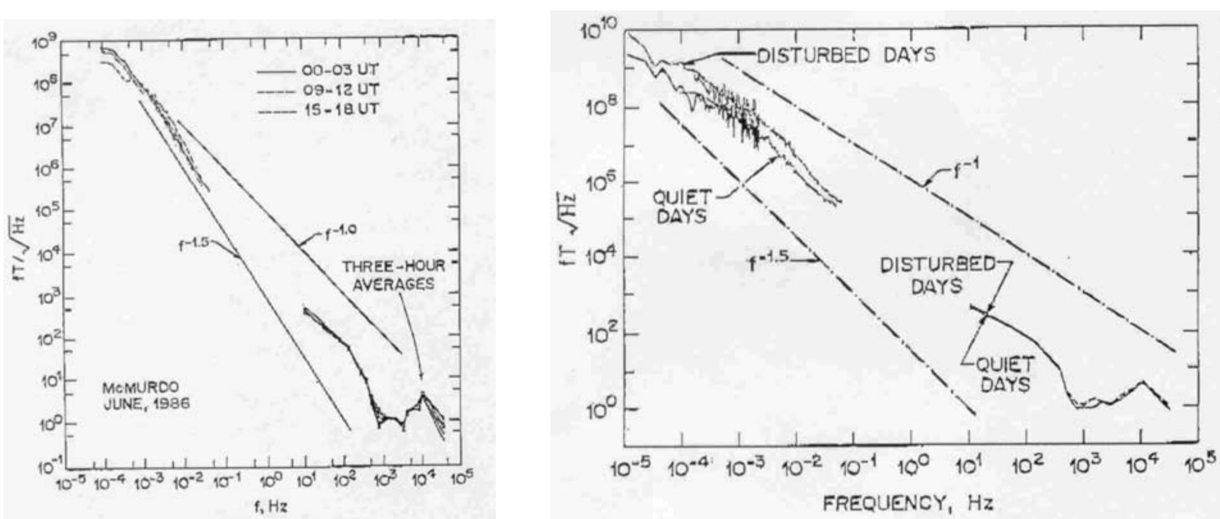


Fig. 3: Average Amplitude Spectra for magnetic field variations in June 1986: (a) Monthly three-hour averages for different three-hour intervals; and (b) Daily averages for three geomagnetically quiet and disturbed days, respectively [copied by permission of the authors from GRS 17(10): 1593 – 1596, September 1986]

“Arrival-Heights of Hut-Point-Peninsula on Ross Island, Antarctica”, and other similar sites for establishing the **‘Average Amplitude/Power-Spectra’**, especially for the ULF/ELF/VLF spectral bands. Similarly, one of radio astronomy’s prime goals is to determine the ‘*virgin radio signatures’* before modern civilization was perturbing it. For technological applications it is essential to know as precisely as ever possible the average characteristics together with reproducible lower and upper (peak-power) bounds within which man-made systems must operate [46-51]. Some of the extracted schematic electro-*magnetic field spectra* are presented in Figs. 2 - 5, providing information on the natural e-m emission and noise source mechanisms, as well as short and long term changes [102]. Whereas in Fig. 2a the galactic and planetary plus terrestrial aeronomy noise is portrayed together with the ‘spherics’ of the Schumann resonance waves [16, 103, 171] below 100 Hz, the solar-terrestrial noise is characterized in Fig. 2b; and diurnal, monthly and quiet versus disturbed amplitude spectra are displayed in Figs. 3a & b. Many more graphs and tables are required for explaining spatial and diurnal variations regarding sun-lit and night, as well as polar versus equatorial variations; and here we refer to Akasofu [1-3], and others [46-51], for further detailed background information.

Seismo-genic Signatures: Of specific interest are the tectonic-stress related signatures, which

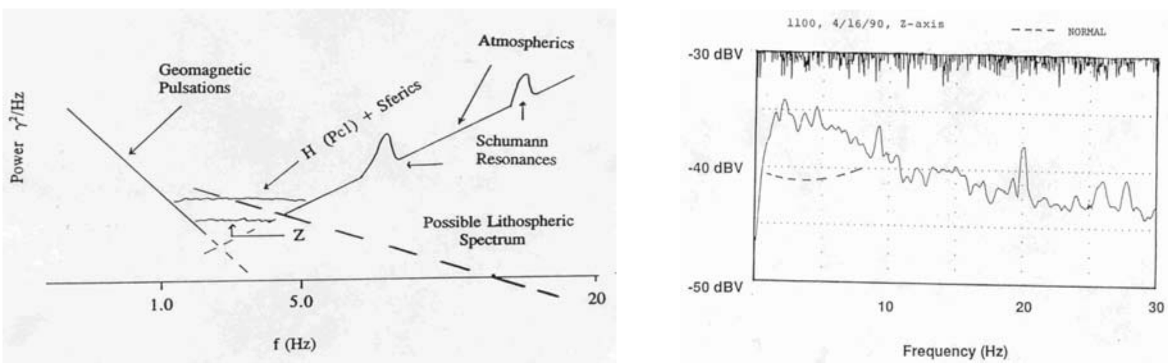


Fig. 4: The ***‘Bill-Green-Diagram’*** (a) together with geomagnetic power spectra observed before the Upland Earthquake of 1990 April 17 (b) within ~ 100 mHz and 20 Hz. The dashed colored lines in Fig. 4a indicate spectrum variations during seismo-genic stress events of a lithospheric origin [63-66]; whereas the dashed line in Fig. 4b designates the average *‘quiet-state’* level [41]

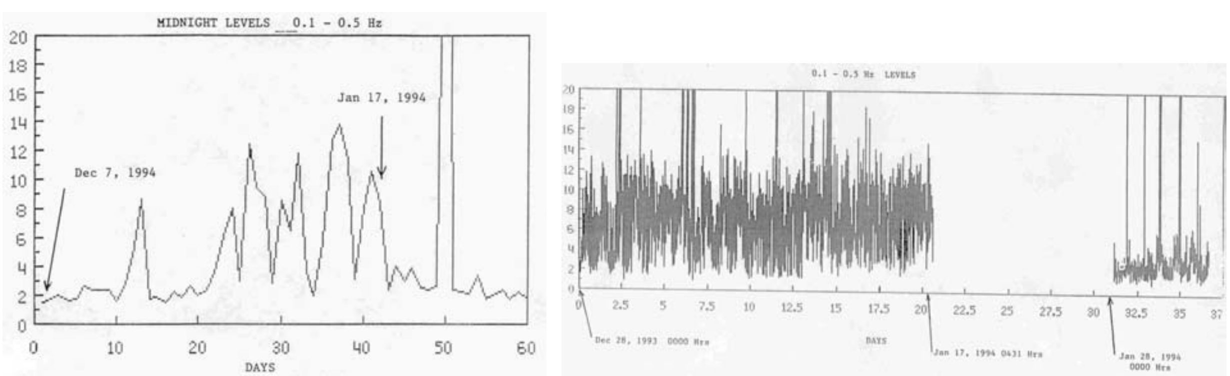
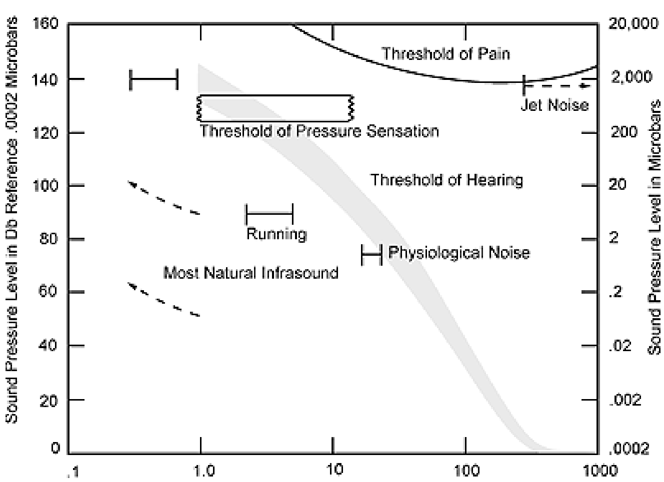


Fig. 5: Average power levels within the .1 - .5 Hz band observed during 1993 Dec 28 to 1994 Feb 04 for the Northridge Earthquake of 1994 January 17: (a) Average midnight levels; (b) the hourly averaged levels (vertical coil sensor) [41]

reside within the natural noise dip between ~100 mHz and ~ 20Hz, with a broad minimum between 2 Hz and 5 Hz as shown in Fig. 4. In Fig. 4a [22, 37-41; 63-66], a schematic diagram, first conceived by the late Dr. Arthur W. (Bill) Green (*1929 July 02, †2001 December 12) and designated the "*Bill-Green-Diagram*", shows the natural average geomagnetic power spectrum in the range of 0.1 Hz to 20 Hz with the fine colored lines depicting the observed spectral variations conjectured to result from lithospheric events [61-66]. In Fig. 4b the averaged power spectrum variations within about 1 Hz and 5 Hz observed at the NOSC-Seaside ULF/ELF Observing Station, Point-Loma, San Diego before the Upland Earthquake of !990 April 17, are shown [41]. The hatched *'colored lines'* are identifying the average power levels, which pulsate with periods of several hours to days. These seismo-genic strongly polarization dependent signatures, first discovered by Yoshino and Gokhberg [61,178-182], can be distinguished from the solar-induced and other man-made ULF-noise by their polarimetric distribution functions [17, 19, 20, 135]. This is now made possible due to the highly improved digital ULF/ELF vector-signal sensing metrology, digital filtering, processing and recording techniques [68-72]. Because such polarization and angle-of-arrival dependent natural *"seismo-genic (electro-magnetic earthquake related) signatures"* are being recorded at ground level, in the atmosphere, and in space with increasing persistency for almost every recent major tectonic stress event (subject to available recording stations) by means of passive sounding – worldwide – often several months before the stress-release occurs, these hitherto little understood phenomena require the enforced reduction of ULF man-made noise-sources to its absolute minimum within this ULF/ELF spectral band. The undesirable ULF noise sources are created by car/electric-transportation, industrial equipment of poor EMC performances especially with poor suppression of higher order harmonics [37-41], and interference from sub-aquatic communications. Figs. 5a & 5b display some of the characteristic seismo-genic signatures observed before and prior to the Northridge Earthquake of 1994 January 17, together with commonly occurring man-made and also natural noise due to spherics and solar-induced signals during active auroral periods, which can however be filtered out due to their distinct polarization-dependent distribution functions; and we refer especially to the three eye-opening Workshop Proceedings on the subject matter published by Hayakawa et al [70-72].

Infrasonic Pressure Sensing: More recently, it was shown that essential benefits maybe reaped



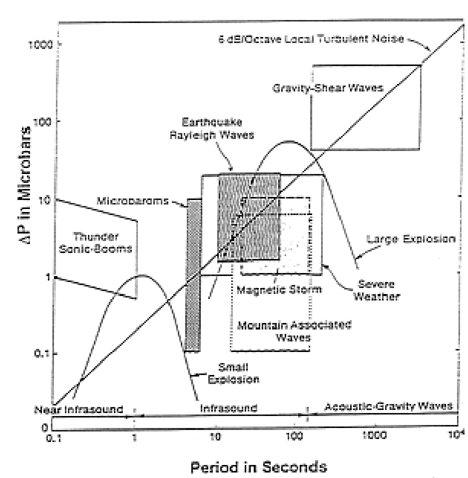


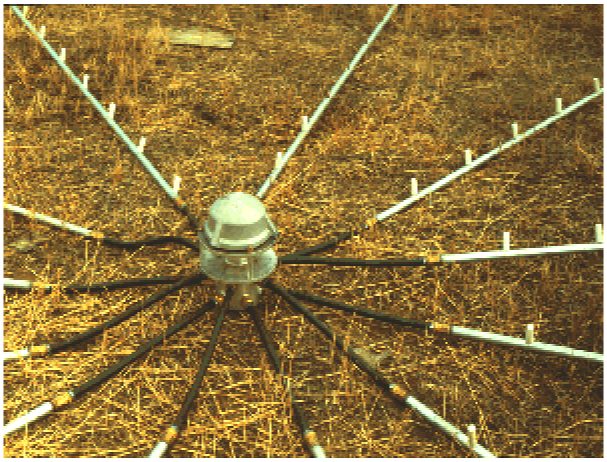
Fig. 6 Typical signal sound pressure levels as a function of frequency, using the threshold of human hearing as a reference (http://www4.etl.noaa.gov/infra/infrasonic.html).

by placing to each ULF/ELF-Sensor system parallel and at the same location an Infrasonic & Near-Infrasonic Surface-Atmospheric Pressure Sensor System (Fig. 7) for the detection and identification of catastrophic surface phenomena such as tsunami and earthquakes, and other micro-seismic events [166]. More attention needs to be paid toward joint multi-media Electromagnetic & Acoustic Near-field & Far-field Remote Sensing. Infrasound is radiated by a variety of geophysical processes including earthquakes, severe weather, including foremost clear-air downbursts and tornadoes, volcanic activity, geomagnetic activity, ocean waves, avalanches, turbulence aloft, and meteors [4, 16]. The general properties of these signals are described in the context of the measurement challenges presented in detecting them. A brief history by Bedard [11-16] provides background concerning the evolution of infrasonic detection technology (see www4.etl.noaa.gov/infra/infrasonic.html). Recent improvements in both hardware and processing software have made passive detection and identification of infrasonic sources on a continuous basis practical and should lead to valuable operational applications. The detection of meteors, meteorites, and space debris is an area reviewed to indicate the capabilities and uses of infrasonic observing systems. The fact that infrasonic systems together with seismic, hydro-acoustic, and radionuclide systems are planned for the International Monitoring System offers wide opportunities for future synergistic research and some of these are indicated [11-16].

Table 1. Infrasonic Observatories and Potential Areas for Data Interpretation and Imaging

PHENOMENA	**Data Interpretation and Imaging**
(a) Avalanches	- Location, Depth, Duration, Type (?)
(b) Earthquakes & Seismic Waves	- Ground Motion, Magnitude, Source Region Details Precursors (?)
(c) Explosions & Missile Launches	- Location, Yield
(d) Geomagnetic Activity	- Location of Particle Impact Zones
(e) Meteors, Space Debris, Supersonic Aircraft	- Type of Entry 1. Explosive, Lower Atmospheric 2. Shock, Upper Atmospheric - Meteor Size and location - Ablation Rates (?)
(f) Ocean Waves (resulting signals are called micro-baroms)	- Location of Wave Interaction Areas, Wave Magnitude, Wave Spectral Content
(g) Severe Weather	-Location, Total Storm Energy, Storm Processes (?)
(h)Tornadoes	- Location, Core Radius, Vortex Column Length (at closer ranges), Formation Processes (?)
(i) Turbulence	- Location, Spatial Extent, Strength (?), Causal Mechanisms (?)
(j)Volcanoes	- Location, Energy Released, Eruption-potential (?)

The vertical scales are in dB relative to .0002 microbar, the threshold of human hearing (left scale) and also the absolute pressure in microbars (right scale). The threshold of hearing and the threshold of feeling cross over at a frequency of about 20 ~ 30 Hz, which means that frequencies



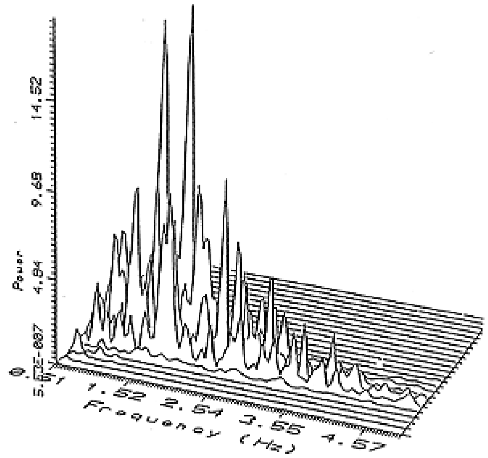


Fig. 7: Infrasonic recording sensor system (7a) with typical pressure amplitudes of infrasonic signals (7b) as a function of period in seconds with proposed definitions for the various frequency ranges indicated (see http://www4.etl.noaa.gov/infra/infrasonic.html).

below this point are felt rather than heard. Other reference points on this plot include the levels and frequencies of physiological noise and typical hydrostatic pressure changes produced by the small altitude changes involved with running or walking. Fig. 7b is intended to provide a reference point for understanding the range of minute pressure changes usually occurring for atmospheric infrasound.

b) Natural Electromagnetic Characteristics within the ULF to LF/MF/HF Spectral Region

Solar-Terrestrial Sources: The major natural electromagnetic background noise emissions are generated by solar-induced currents in the ground as well as in the ionosphere [1-3, 29, 63-66, 68-72, 82, 145], which differ widely from point to point, and are strongly dependent on sun-spot activity. There exist now several ground-based as well as satellite systems providing reliable hourly and daily sunspot images as well as prediction data. As an example, we refer here to the huge 4x64 C (5.2 cm)-band 3m-dish-antenna cross-interferometer of the Russian Academy of Sciences, Siberian Branch, Irkutsk Science Center, Institute of Solar Terrestrial Physics, *'Siberian Solar Radio-astronomic Telescope'* or "SSRT *Radio-Helio-Graph*", at Badharij – about 60km southeast of the spa-center of Arshan in the Tunka Valley National Park, Southwest of Lake Baikal. The tri-hourly image records are available on: http://www.eastsib.ru/~ssrt , and a typical sun-spot image, downloaded on 2002 January 21, is shown in Fig. 8. Other web sites of solar observatories are http://www.ngdc.noaa.gov/stp/SOLAR/IAUWGdoc.html from the Whole Sun Catalog at http://arthemis.na.astro.it/wsc .Various ground-based and a multitude of highly useful satellite instruments for predicting the solar-terrestrial interaction are maintained by NOAA, and information is available via the NOAA Solar-Terrestrial Physics Information Center at Boulder; and ESA had operated the Helio-Sat-1, and is currently in the process of preparing

Helio-Sat-3 for launch , which is placed at the sun-earth equilibrium geostationary distant and measures the incoming solar flux, which then maybe

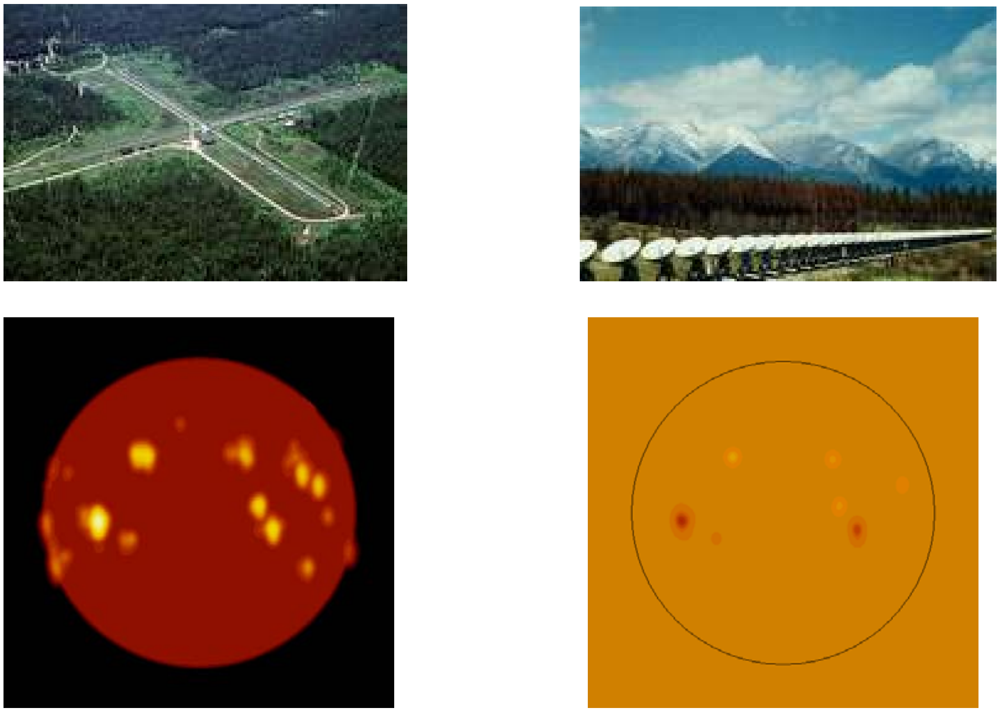


Fig. 8: Sun-spot activity image of the sun obtained with the *'SSRT Rdio-Heliograph': (a) The SSRT C-Band Helio-graph; and (b) typical sun-spot image of 2002 January 21: 04:48*

used for predicting rather accurately the solar-terrestrial storm impact on the Earth's surface. Below, in Fig. 9, the pertinent Eleven-year solar sunspot cycle is shown; and further detailed information is available through the pertinent web-site of NOAA Space Weather Now utilizing the SOHO (Solar & Heliospheric Observatory: http://sohowww.nascom.nasa.gov) as well as the ACE (Advanced Composition Explorer: http://sd-www.jhuapl.edu/ACE/ACE_FactSheet.html or http://www.srl.caltech.edu/ACE)

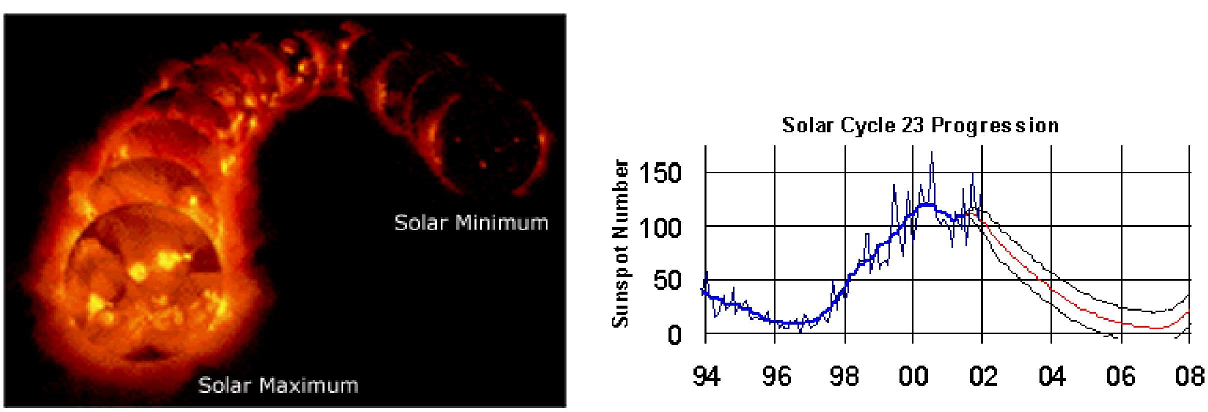


Fig. 9: NOAA Space Weather Now: Current eleven-year Sunspot cycle; for further details see: http://www.sel.noaa.gov/SWN/index.html

Deep-Sounding and GPR: The Earth's crust, and its geologic layers possess very distinct resonance behavior in these spectral regions, and so does dense tropical vegetation at the upper HF-Band.

The terrestrial sub-surface structure can be assessed mainly by methods of active remote sensing with the aid of ground penetrating radio sources, and also Ground Penetrating Radar (GPR) at the upper HF frequency band into the VHF Band. The GPR deep sounding and sub-surface imaging techniques are highly polarization sensitive. Because of the highly heterogeneous nature of the rough surface and granular soil structure, severe speckle and background clutter perturbs the observed signatures; novel polarimetric noise instead of coherent polarimetric GPR technology is implemented, which is also less sensitive to industrial noise and the natural electromagnetic noise generated by solar-induced currents in the ground and ionosphere [55, 133, 155, 166, 168].

Ground Penetrating Radar (GPR) systems are used by scientists and practitioners to explore the shallow subsurface of the earth and probe into man-made structures. GPR has the highest resolution of any geophysical tool for non-invasive subsurface investigation. In addition, it is one of the very few geophysical methods capable of detecting non-metallic objects and dielectric contrasts, such as organic chemical contamination, plastic land mines, plastic gas pipes and fibre optic cables. To penetrate the ground effectively, GPR operates within a frequency range from tens of megahertz to several gigahertz. However, high resolution requires a broad bandwidth, which is easier to achieve at higher frequencies. In addressing this compromise, GPR systems are designed to operate across many different frequency bands centered from 10 MHz to 3 GHz, with each band having a fractional bandwidth exceeding 100%. This characteristic puts GPR into the most extreme class of ultra-wideband radars. Like most other ultra-wideband technologies, GPR devices currently fall outside of any formal regulatory framework, and concerns have been raised about their potential interference with licensed radio frequency receivers.

RF-EO $LiNbO_3$ Vector-signal Transducers: Very considerable technological advances were made by the leading Japanese R&D team of Motoyuki Sato [42, 43], who first experimented with "*Opto-Electronic RF-Transducer Field Sensor Arrays with bandwidth of about 0.01 – 3GHz"* in borehole GPR, which cuts down very substantially on sensor seize & weight, RF & noise interference, and especially on cost. A typical EO-RF ($LiNbO_3$) transducer configuration is shown in Fig. 10, which can be applied directly to recovering the coherent and noise polarization scattering matrices. This EO-RF ($LiNbO_3$) transducer concept was further developed by TOKIN (see web site: http://www.tokin.co.jp/english/index.html), can and is being applied currently to a wide variety of household appliances, auto/rail transportation systems, and other environmental measurement devices, and it should assist most strongly in cutting down [155, 156] decisively on infrastructure and industrial RF noise and RF interference. More so, this novel technique is currently applied to the development of EO-RF-Transducer SAR-Array-Antenna configurations, which shows every reason of becoming highly efficient space & weight saving, wide-band fully polarimetric coherent recording devices as well as being extremely well suited in cutting down on the reception of noise and interference. Definitely, this kind of technology must be rapidly

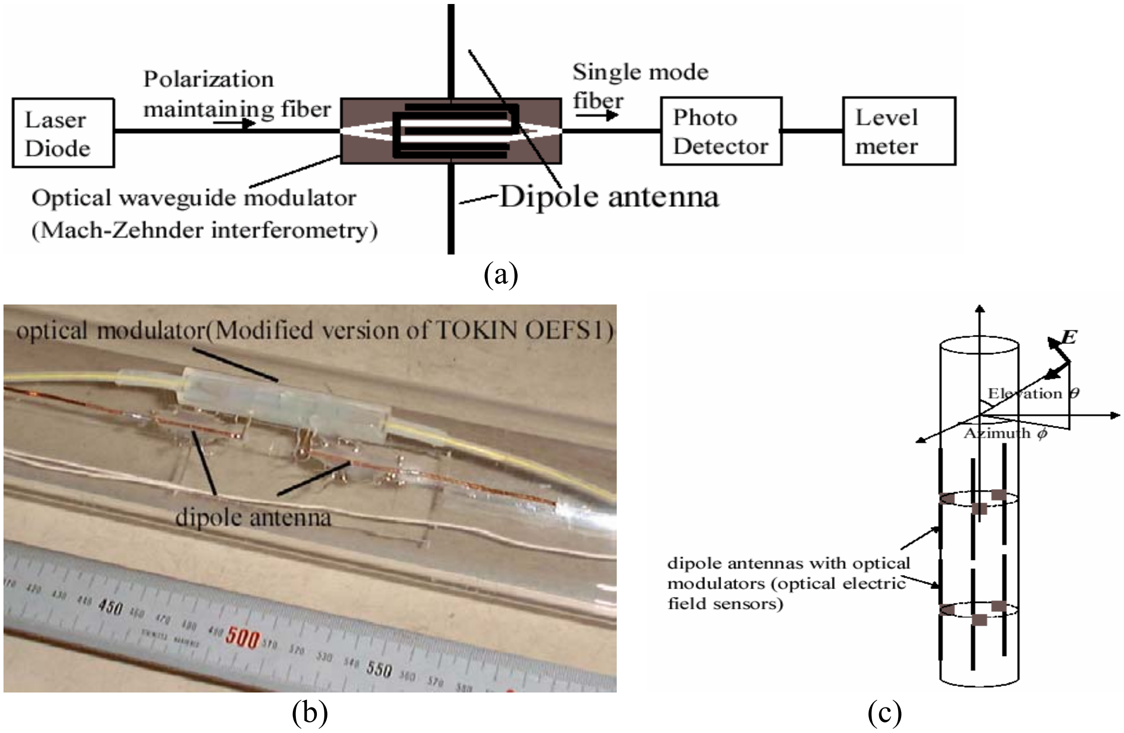


Fig. 10: The EO-RF transducer field sensor system in GPR borehole technology (Motoyuki Sato): (a), OE Field Sensor System (b) TOKIN OEFS1 dipole antenna with OE transponder, and (c) Deployment of field sensor array for directional borehole radar (for details see: Ebihara & Motoyuki, 2000 [42] & 2002 [43])

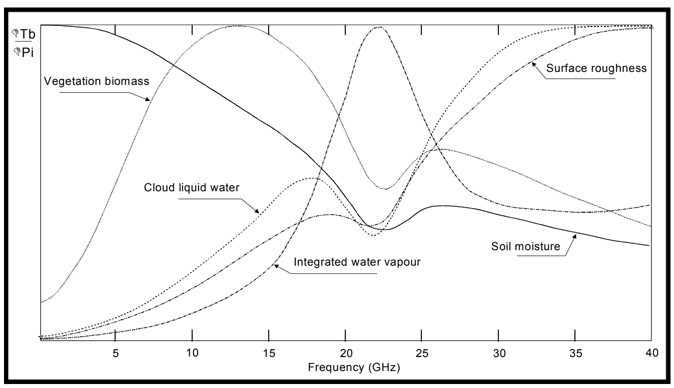
advanced, perfected and applied across the entire electromagnetic spectrum; and we refer here, for example, to the well done web site of Tokin (http://www.tokin.co.jp/english/index.html).

Vegetation Penetration and Biomass Estimation in Dense Tropical Jungle Forests: Very dense and highly conductive vegetation which resides within dense tropical jungles require active remote sensing at frequencies as low as the upper HF and the lower VHF spectral domains, and there does exist the realistic demand for making available pertinent frequency bands on a time-sharing basis for this purpose. Under certain precipitation and vegetation conditions, dense tropical jingle forests behave close to conducting soils, and for SAR remote sensing, we need to develop – at least – airborne POL-SAR Imaging and Sounding systems, similar to CARABAS, operating within (800 KHz) 1 Mhz to 100 MHz (200 MHz); and we refer here, for example, to the well-done web site prepared for the CARABAS system.

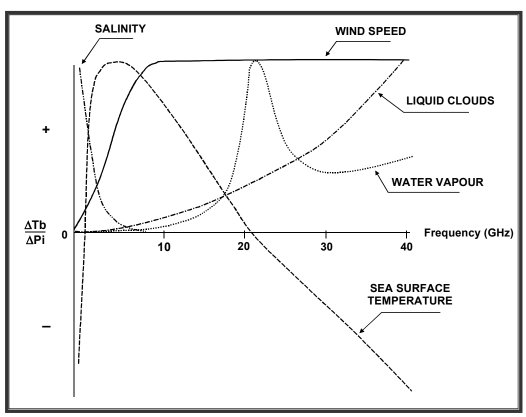
c) Natural Electromagnetic Terrestrial Surface & Vegetative Characteristics within the VHV/UHF Bands [18-25, 31-34, 44, 45, 73, 80, 81, 105, 154, 159, 172, 173, 175, 176, 177]
The major contributors to the natural electromagnetic background noise are ionospheric sources and especially propagation through the ionosphere becomes polarization-dependent resulting in the Faraday polarization state rotation and spectral band widening effects, which can impair both passive and active remote sensing severely depending on the magnetic latitude and longitude plus altitude. Figs 10a & 10b display some characteristic average brightness distributions, which

need to be taken carefully in consideration in the design of both passive and active sensor systems.

Within the VHF/UHF Bands the terrestrial surface with its soil/rock layers, vegetation and water/snow/ice covers possess some of its most distinct characteristic resonances for biomass determination and vegetation cover plus soil-parameter description [19-21, 73, 87, 131, 132]. These facts are displayed in the Figs. 11 to 12, demonstrating how the performance and duty curves for specific geographic regions need to be established; and in Table 2 a crude estimate on penetration depth into dry soils is presented for various microwave sensing bands. Because of the fact that within the 100 KHz to at least 20 (40) GHz vegetation covers and soily layered under-burdens display very species-critical behavior, it is not meaningful to present soil and vegetation transmissivity curves; instead some recent results of POL-SAR Imaging are presented in Fig. 13. A POL-SAR image (AIRSAR: SF-Bay Region) evaluation utilizing the unsupervised Cloude-Pottier H/A/Alpha algorithm with implementation of the Lee-Polarimetric-Speckle filter is provided.



(a)



(b)

Fig. 11: Sensitivity of brightness temperature to geophysical parameters over (a) land and (b) ocean surfaces (from Kerr et al.)

Whereas at polar and sub-polar boreal and austral regions the higher K/X/(C)-Band spectral bands may be ideally suited for ice/snow/vegetation cover determination using air/space-borne SAR, the closer one is monitoring toward the equatorial densely vegetated tropical belt, the lower the critical frequency bands become [21]. For example, at the temperate mid-latitude belts the C/S/L-Bands maybe optimal; and in the equatorial belt the L/P/VHF/HF-Bands are ideally

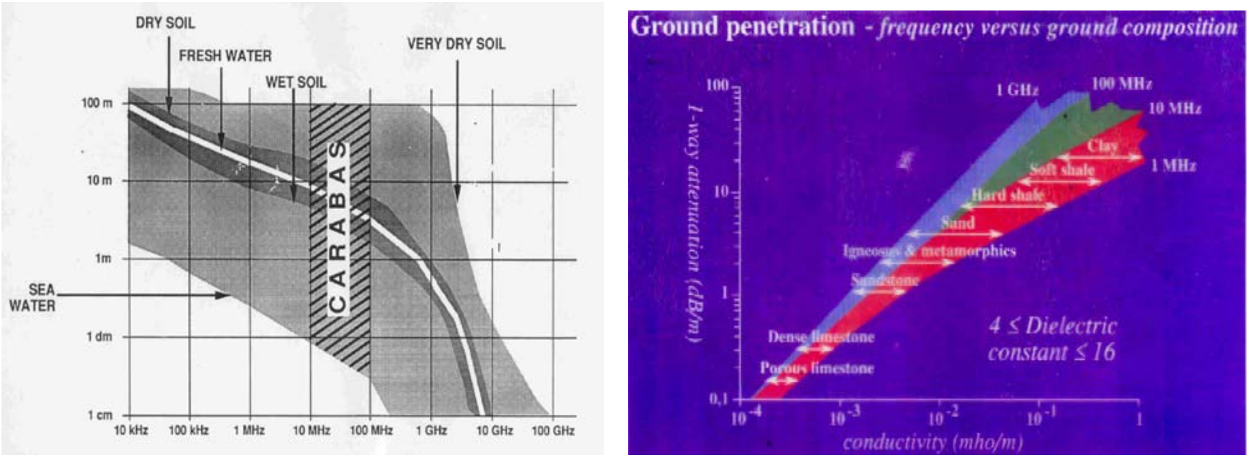


Fig. 12: CARABAS Penetration Capabilities

required. However, for space-borne SAR sensors and imagers, great care must be taken in correcting for Faraday-Rotation & Spectrum-Spreading effects at the L-Band and below; and very decisive progress was made in this respect. (www.foa.se/eng/carabas.html)

Table 2: Wavelengths and Penetration Depth of Common Dry Terrain Surfaces for Conventional Radar Bands (very crude estimates)

Radar Band	*Nominal Wavelenght [cm]*	*Approximate Depth [cm]*
K	1	1
X	3	3
C	5	5
S	10	10
L	25	25
P	50	50

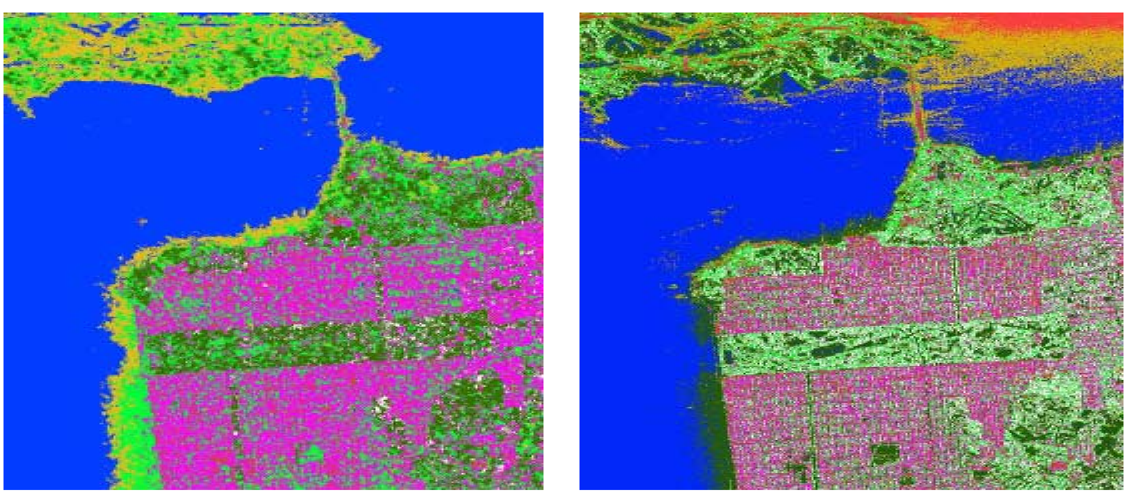


Fig. 13: Unsupervised polarimetric SAR image classification using the Cloude-Pottier H/Alpha algorithm (left) with Lee-Wishart polarimetric speckle filter applied (right) of S-F Bay Region

The major sources of interference for both the passive radiometric as well as active SAR sensors and imaging systems are definitely the Communications, Transport/Navigation (GPS), the Defense & Security bands. The spectrum of about 100 KHz to 10 GHz is cramped full, and the "***Active plus Passive Remote Sensing Community"*** may have no other choice but putting up a stiff, very forceful fight for regaining at least some narrow but also some wide bands within this spectral region. The underlying physical laws of nature dictate and fully support this quest, and

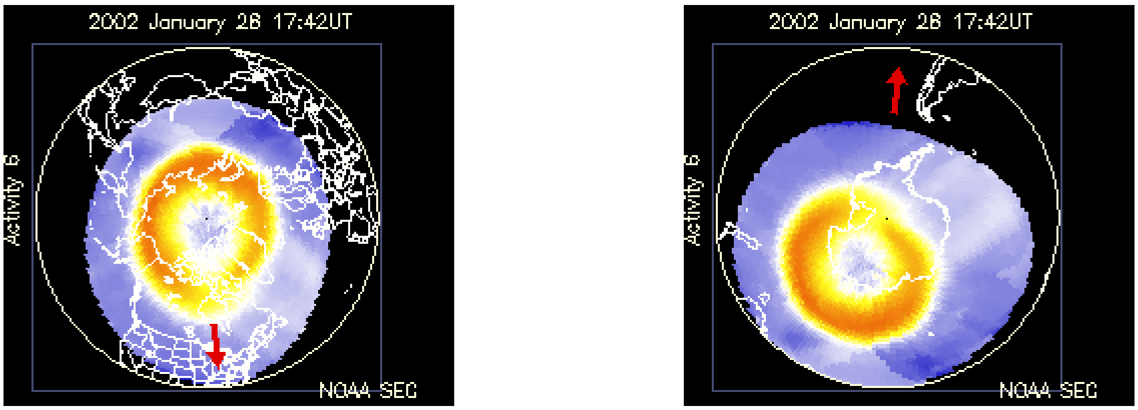


Fig. 14a: Auroral Activity Extrapolated from NOAA POES (NOAA-16 satellite). For further details see: http://www.sel.noaa.gov/pmap/index.html and the web sites of the list of solar observatories: http://www.ngdc.noaa.gov/stp/SOLAR/IAUWGdoc.html) from the Whole Sun Catalog at http://arthemis.na.astro.it/wsc/.

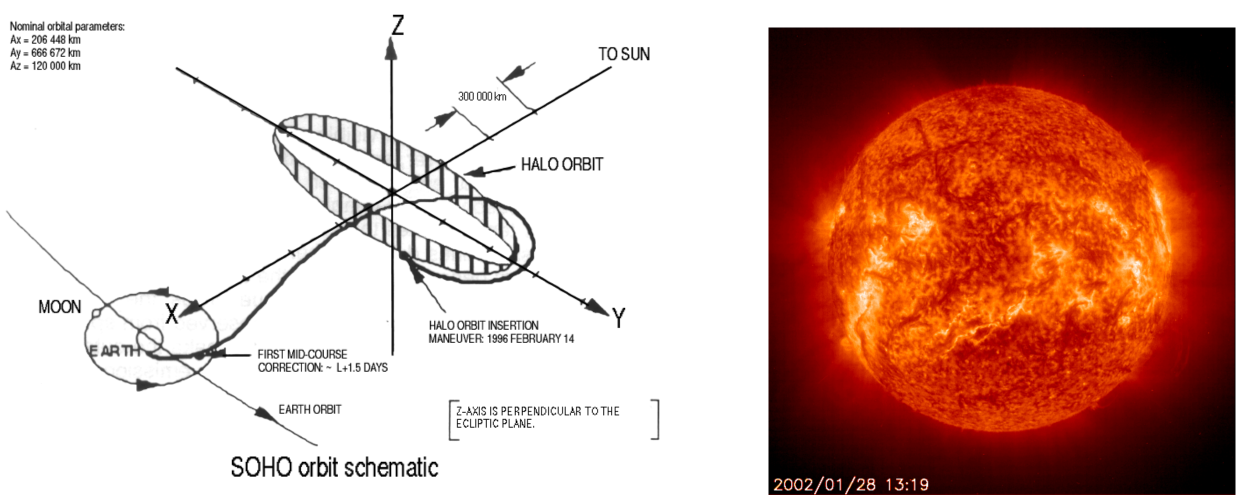


Fig. 14b: The SOHO (Solar & Heliospheric Observatory: http://sohowww.nascom.nasa.gov) satellite is one of several spaceborne solar wind prediction observatories

irrespective of various methods of available and near-future RFI reduction techniques, we – *the passive & active remote sensing community* - need to acquire our own permanently assigned and licensed bands. The request for extending the L-band by assigning more bandwidth, and for a P-band window are currently being submitted to the ITU/WMO; and will be further analyzed below.

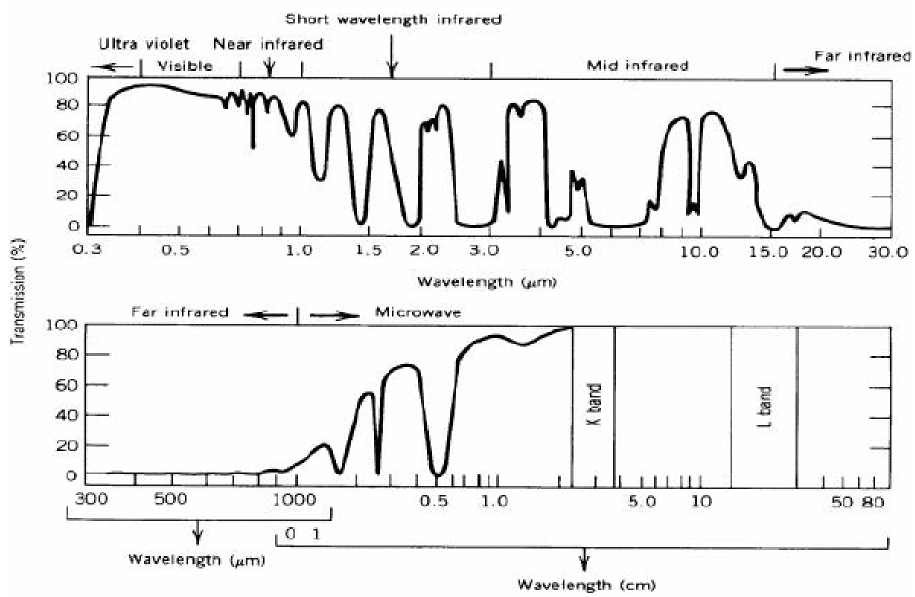


Fig. 15: Transmission Spectrum of the Earth's Atmosphere

d) Natural Electromagnetic Microwave & Millimeter-wave Characteristics
The vegetative layers display their most distinct resonance behavior in these spectral regions; and water vapor resonances begin to appear, which become more pronounced as one approaches the infra-red spectral domain [73, 82, 83, 116, 144, 167].

Within these spectral bands the major natural electromagnetic background signatures are defined by the Faraday-Rotation effects towards the lower end, and atmospheric gaseous resonances and attenuation windows toward the upper end, as is shown in Figs. 14 – 19. As regards solar-terrestrial storm events, in Fig. 14 pertinent auroral effects are depicted with more information available at the NOAA web-site, and later on in Fig 19.

As is to be expected, this spectral region of the electromagnetic spectrum is also ram-packed, yet it is so very essential for a multitude of environmental remote sensing tasks that requests for opening up various narrow and also some ultra-wide band windows be made and realized subject possibly to well arranged and licensed time-sharing procedures.

e) Natural Absorption and Resonance Signatures of the Atmospheric to Mesospheric Covers: 18 10 (+9) to 10 (+14) [56-59, 89-92, 99, 110-112, 115, 138-140, 146-148]
Within these spectral bands atmospheric to mesospheric gases including water vapor display their characteristic resonance behavior, and establish the **"Natural Electromagnetic Background Signatures**", which must definitely be treasured and protected from the blatant misuse of the telecommunications complex as designated and licensed bands at least for communication within the atmospheric to ionospheric covers. These atmospheric propagation characteristics are displayed in Figs. 17/18, and those are most essential for passive monitoring of meteorological phenomena and thus must be protected most carefully.

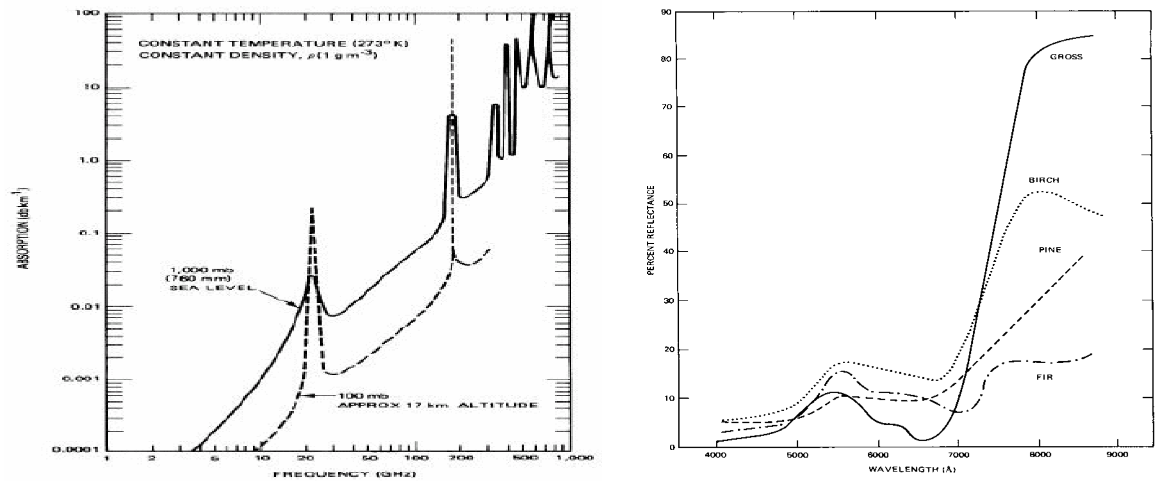
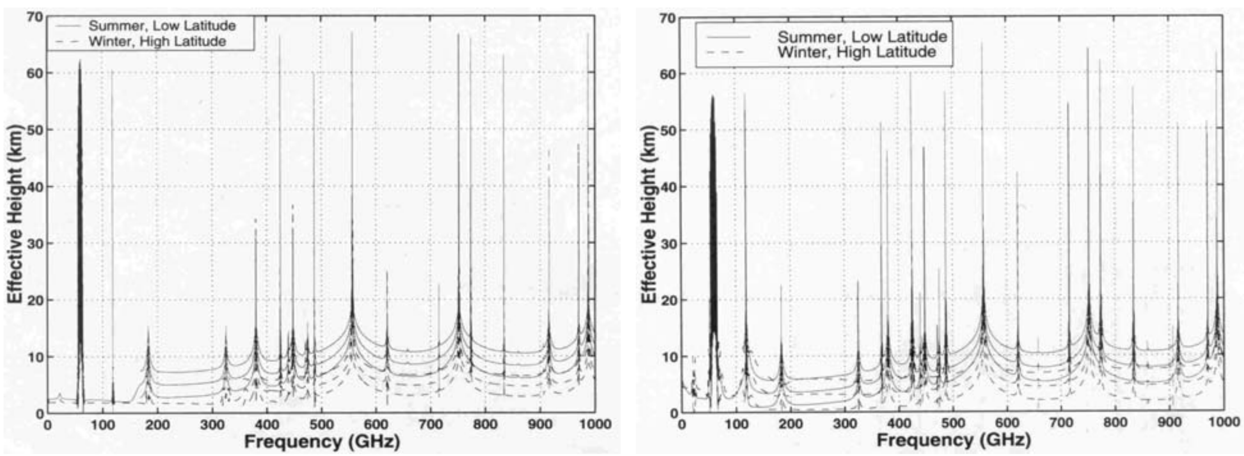


Fig. 16: Absorption Spectrum for Water Vapor and of Spectral Signatures of Vegetation



(a) (b)

Fig. 17: (a) Effective water vapor and (b) effective temperature sensing for two extreme atmospheric profiles disregarding ozone influence using nadir satellite view over ocean.

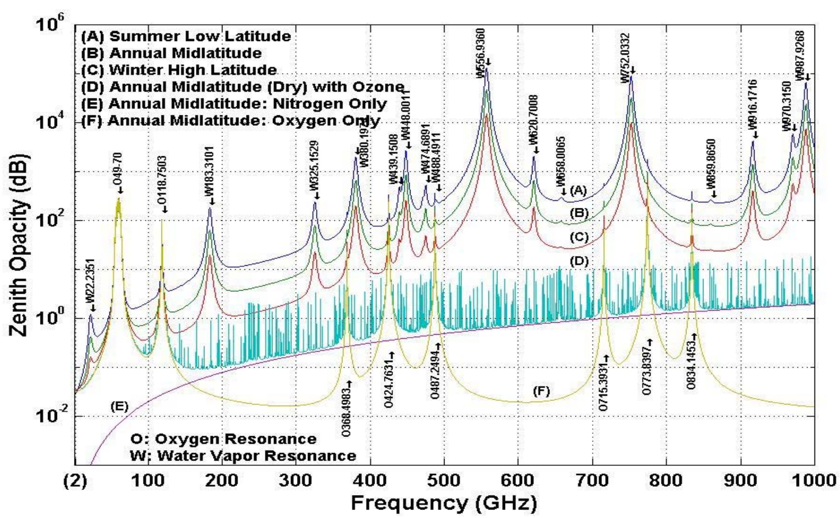
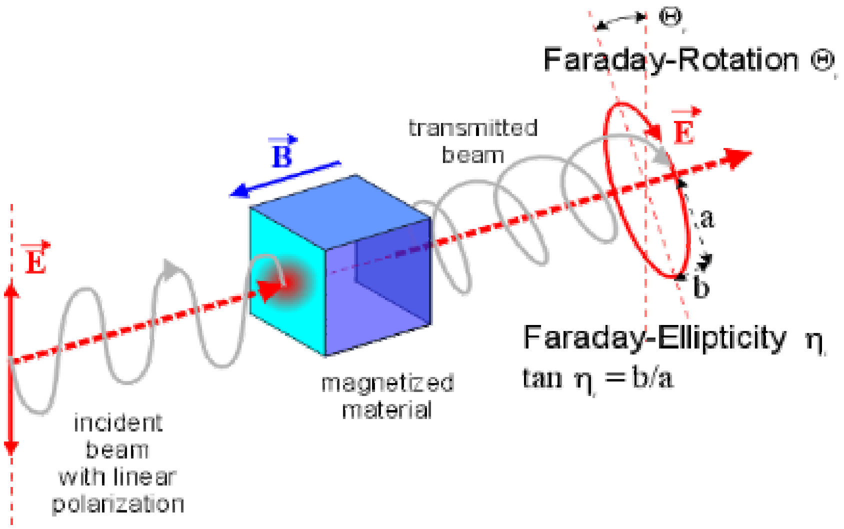


Fig. 18: Atmospheric spectrum in the MW/Sub-mm range (from Klein and Gasiewski, 2000)

f) Ionospheric & Magnetospheric Natural Signatures and the Faraday-Rotation Effect
Ionospheric and magnetospheric background characteristics are most essential factors in designing various passive and active remote sensing space-borne but also air-borne monitoring systems, especially when operated in polar auroral regions. Figs. 14 and 19 provide schematic pictures of the various ionospheric phenomena and its associated impact on ionospheric propagation, and we refer to the web-sites cited in Fig. 19. Of specific interest is the Faraday rotation effect as shown in Fig. 19 to the operation of communication and remote sensing plus surveillance satellites – passive and active, and considerable studies are currently being conducted on how to reduce the effect on orbiting satellite microwave sensor systems [54, 107-109, 160, 183]. Here we include some graphs on how to deal with reducing effects of Faraday rotation for both passive and active, fully polarimetric sensors, as provided in Figs. 19& 14.



http://www.physik.fu-berlin.de/~ag-fumagalli/snom/

One-way distance through a uniform ionosphere, propagation normal to the magnetic field, in which a linearly polarized wave, E-field 45 degrees to the magnetic field lines, will become elliptically polarized to the indicated degree.
http://www.tuc.nrao.edu/~demerson/ionosphere/ionopol.html

AR is the *Axial Ratio* of the polarization.				
	50 MHz	**144 MHz**	**432 MHz**	
Circular: (AR=0 dB)	100	2800	76000	(km)
AR=6 dB	70	1700	45000	
AR=10 dB	49	1000	30000	
AR=20 dB	14	400	10000	

Fig. 19: Faraday Rotation Effects. For more information see pertinent web sites provided.

3. Basic Spectral Band Allocations & Demands for Passive and Active Remote Sensing of the Terrestrial Covers, Primarily the Biosphere and the Atmosphere [78-79]

There exist very realistic high-priority demands for hardening the licenses for existing, and for requesting additional narrow as well as ultra-wide band remote sensing windows [62, 116, 136, 149-153, 185-187] for (i) the GPR , and (ii) for the space remote sensing community [93, 94, 167], which need to be protected and licensed for the ***"Earth Exploration Satellite Services (EESS)".*** Licensing may include well arranged time-sharing agreements.

a) HF – VHF – UHF Ultra-Wide-Band GPR Demands

Ground Penetrating Ultra-Wide-Band Demands: GPR systems have been operated since the 1970's and there is very little evidence that any interference has been caused during this period. There are good technical reasons to support this. The number of GPR systems is very small compared with the number of mobile phones and they are often operated away from areas of high population density. Nearly all of the emitted energy is directed into the ground, where it dissipates quickly. To maximize performance, every effort is made to keep the small fraction that might otherwise escape as low as possible by antenna shielding and close ground coupling. In addition, GPR systems are active for only very brief intervals at a time that are separated by long inactive periods. Even if active operation was continuous, the low average transmitted power greatly reduces the probability of actual harmful interference.

Within the European Union (EU), appropriate legislation has not yet been passed which will permit the general use of ultra-wideband technology such as GPR. Hence each member country has dealt with GPR on an individual basis subject to approval by the national radio licensing authority. There is also no defined frequency band for which a harmonised European specification exists. However there are initiatives being co-ordinated by the European Telecommunications Standards Institute (ETSI). EU approval will be necessary to bring it into force across Europe. **In the UK** GPR technology has been used under temporary use licenses under approval by the UK Radiocommunications Agency who is currently working on legislation to permit the use of GPR. **In Germany and Belgium** the appropriate licensing authorities have permitted the use of GPR systems under strict controls. In practical terms this involves the use of a "dead man's handle" to require positive operation of the transmitter as well as a proximity sensor to ensure proper coupling with the ground.

In Japan, the use of GPR systems has been permitted under domestic regulations associated with *"weak signal radio equipment*". The official rules require the equipment to be measured in air at nadir (ie. measurements taken in the direction of antenna boresight). However, waivers to this requirement have been given to GPR systems that are equipped with a shut-off switch that automatically stops the radiation when the GPR system is lifted from the ground surface, or is not operated horizontally. This additional requirement acknowledges that emissions into the air from GPR under normal operating conditions are unintentional.

The US Federal Communications Commission (FCC) is in the process of proposing modifications to their Part 15 Rules to permit unlicensed use of ultra-wideband transmission systems such as GPR. The current Part 15 rules pose two primary obstacles to GPR. First, the ultra-wide bandwidth of GPR systems causes non-spurious emissions to fall in licensed and restricted frequency bands, which is prohibited under the current Part 15 rules. Second, the current emission measurement procedures specified in the current Part 15 rules were developed for narrowband systems and are inappropriate for ultra-wideband systems such as GPR. While proposing new rules, the FCC have acknowledged that ultra-wideband devices appear to be able to operate on spectrum already occupied by existing radio services without raising interference.

Table 3: Compatibility Studies by Frequency Band for Earth Exploration Satellite Systems (EESS)

Frequency Band (MHz)	Allocation Status	Typical SARs Studied	EESS (active)/SR (active)	Other Services in Band Included in Compatibility Studies
420-470	No allocation, 6 MHz bandwidth under consideration in WRC'03 Res. 727	(F)	EESS(active), SR(active)	RADIOLOCATION,RNSS, AMATEUR, FIXED, MOBILE
1215-1300	Primary (WRC'97)	SIR-C, JERS-1	EESS(active), SR(active)	RADIOLOCATION,RNSS, Amateur (secondary)
3100-3300	Secondary (WRC'97)	ALMAZ	EESS(active), SR(active)	RADIOLOCATION
5250-5460	Primary (WRC'97)	RADARSAT, ASAR, ERS1/2, ENVISAT ASAR(F), RADARSAT-2	EESS(active), SR(active)	RADIOLOCATION (active and secondary), AERONAUTICAL RNSS
5460-5570	No allocation, under consideration in WRC'03 Res. 736	(F)	EESS(active), SR(active)	RADIOLOCATION
8550-8650	Primary (WRC'97)	(P)	EESS(active), SR(active)	RADIOLOCATION
9500-9800	Primary (WRC'97)	X-SAR	EESS(active), SR(active)	RADIOLOCATION, RADIONAVIGATION
13250-13750	Primary (WRC'97)		EESS(active), SR(active)	AERONAUTICAL RNSS, RADIOLOCATION
17200-17300	Primary (WRC'97)		EESS(active), SR(active)	RADIOLOCATION
24050-24250	Secondary (WRC'97)		EESS(active)	RADIOLOCATION, Amateur (secondary)
35500-35600	Primary (WRC'97)		EESS(active), SR(active)	RADIOLOCATION,METEOLOGICAL AIDS
78000-79000	Primary by RR footmote S5.560 (WRC'97)		EESS(active), SR(active)	
94000-94100	Primary by RR footmote S5.562 for spaceborn cloud radars only (WRC'97)		EESS(active), SR(active)	RADIOLOCATION
130000-131000	Primary (WRC'2000)		EESS(active), SR(active)	RADIOLOCATION
192000-195000	Primary (WRC'2000)		EESS(active), SR(active)	RADIOLOCATION

In May 2000, the FCC published a Notice of Proposed Rule Making (NPRM) on ultra-wideband transmission systems for public comment before the new rules are ratified. An announcement of the new rules has been delayed but is expected to be made in early 2002. The implications of these new rules will be presented (see URSI-GA-02 SS-JFC) [78, 79].

b) Micro/Millimeter-wave Demands for "Earth Exploration Satellite Systems (EESS)"

Frequency Bands with Compatibility Studies- 420 MHz to 195 GHz: There are some thirteen frequency bands presently allocated to EESS (active) and SRS (active), ranging from 1.215 GHz to 195 GHz, as shown in Table 3. In addition, the 420-470 MHz band is under consideration in the WRC-2003 resolution 727, with a resolves to consider provision of up to 6 MHz of frequency spectrum to the EESS (active). Also, the 5460-5570 MHz band is under consideration in the WRC-2003 resolution 736 resolves to consider additional primary allocation for the EESS (active) and SRS (active). The microwave bands include the ten bands in Table 3 from 420-470 MHz to 24.05-24.25 GHz. The millimeter wave bands include the five bands in Table 3 from 35.5-35.6 GHz to 192.0-195.0 GHz. In the following table the existing and the currently desired plus requested spectral windows are listed and identified see Huneycutt et al, URSI-GA-02, SS-JFC) [78, 79].

b-1) P-Band

Of specific interest to vegetation biomass monitoring is the P-Band, and some details on a currently placed request to the ITU/WMO and United Nations are summarized.

Current WRC '03 Studies- 420-470 MHz and 5460-5570 MHz Bands: The WRC-2003 resolution 727 resolves to consider provision of up to 6 MHz of frequency spectrum to the EESS (active) in the band 420-470 MHz. The WRC-2003 resolution 736 resolves to consider additional primary allocation for the EESS (active) and SRS (active) in the band 5460-5570 MHz. One study from the spaceborne active sensor community has analyzed the interference from spaceborne SARs in the band 420-470 MHz into Earth stations, the radio amateur service, fixed service, and ISM equipment, concluding that although there may be occasional interference to the various other services, that the interference will be short in time and will have a very long interval of six months or longer and thus the affected service will not be rendered incapable of operating effectively; the study would need to be extended with a sharing analysis with terrestrial space object tracking radars. Another study by the spaceborne active sensor community analyzes the interference levels of a very low power, low sidelobe spaceborne SAR into the amateur and amateur satellite services, offering that the SAR parameters can be chosen for certain SAR modes to reduce the interference level to acceptable levels.

Separately from demands of the Remote Sensing Community, here also the demand of operating GPS at a second frequency deserves ample airing.

b-2) L/C Band

Next to the operation of the GPS within this band, the well demonstratedL-Band Multi-modal POL-IN-SAR remote sensing capabilities justify the full assignment of a permanent ultra-wide-band window to be assigned and licensed by the ITU/WMO [185-187].

L-Band: Out of the thirteen allocated frequency bands, the 3.1-3.3 GHz and 24.05-24.25 GHz bands are secondary allocations, the 78-79 GHz band is allocated by footnote S5.560, and the 94.0-94.1 GHz band is limited to spaceborne cloud radars by footnote S5.562. Prior to the WRC-1997, JWP 7-8R performed, in some thirteen bands, compatibility studies between the spaceborne active sensors and the radiolocation/ radionavigation services to support the various frequency allocation upgrades from secondary by footnote, to primary allocation. In addition, several experiments were performed to investigate sharing with the radiolocation/ radionavigation services, in the band 1215-1300 MHz. GPS/SAR compatibility was tested during reception of actual GPS satellite signals into the GPS receiver while at the same time injecting SAR interference signals; the GPS experienced only a few tenths of a dB degradation in the tracking loop SNR, which was deemed acceptable. Also, ARSR-4/SAR compatibility was tested at the Washington/Baltimore airport ARSR-4 facility by simulating the tracking of ARSR-4 targets as the antenna rotated, and at the same time injecting SAR-like signals into the front end of the ARSR-4; the ARSR-4 performed nominally even as the I/N was increased to +20 dB, revealing some 30 dB of processing gain for the ARSR-4 system [185-187].

C-Band: The 2003 World Radio-communication Conference (WRC-03) will consider agenda item 1.5 which deals with allocation issues around 5 GHz. In the consideration of this agenda item, potential allocations to the mobile service for use by wireless access systems including radio local area networks (RLANs) in the bands 5150-5350 MHz and 5470-5725 MHz are being contemplated. A new allocation to the fixed service in ITU Region 3 (essentially Asia and the Pacific Rim) for fixed wireless access (FWA) systems is also being considered. At WRC-97, the Earth exploration-satellite service (active) or EESS (active) and the space research service (active) were allocated on a primary basis to the band 5250-5460 MHz for active sensing of the Earth from orbit. Under WRC-03 agenda item 1.5, an additional allocation to the EESS (active) and SRS (active) in the adjacent band 5460-5570 MHz is also being considered as well as an upgrade to the secondary radiolocation service allocation in the band 5350-5650 MHz.

This situation becomes problematic when one considers the sharing possibilities with these possible allocations. It has been demonstrated that sharing between the spaceborne active sensors and systems operating in the radiolocation service is feasible. However, the wireless access systems have difficulty sharing with both the radiolocation service and the EESS (active) and SRS (active). In fact, studies have shown that even one active outdoor wireless access transmitter would exceed the interference threshold of the active sensors. Since there is virtually no way to control the deployment or density of these wireless access devices, this is of great concern to the active remote sensing community. This problem will be discussed in detail.

Short-to-Long Temporal Base-line Repeat-Pass X/C/L/P-Band POL-SAR Intreferometry for Tectonic Stress-Change Monitoring: One rather impressive contribution of C/L/(P)-band SAR Interferometry is related to short – to long temporal base-line bi-static (repeat-pass) interferometry for assessing tectonic surface stress changes in earthquake prone tectonic regions. Here, especially the C-Band ERS-1/2 and L-Band JERS-1 space-borne single-polarization SAR systems, although not designed foe accurate repeat-pass image co-registration, provided convincing results. With the anticipated strong improvement of coherent co-registration capabilities, and fully polarimetric SAR sensors for the RADARSAT-2 (POL-C-SAR) and the Japanese ALOSSAT (POL-L-SAR) plus the partially polarimetric ENVISAT (C-SAR), very rapid advancement of POL-SAR-Interferometry can be expected. Again it is important that both space-bone sensor and ground-region RF noise and interference from man-made source are being reduced to the utmost minimum within the tectonically stressed regions. Furthermore, the active US HighTech21and the EU Cart-wheel X-band bi-static space-borne multi-interferometer configurations should become most instrumental in the rapid advancement of these techniques, although in addition multi-band C/L/P-Band fully polarimetric SAR operation is truly desired.

c) 40 GHz to 400 GHz Meteorological Satellite Sensor Demands (see Guy Rochard et al., URSI-GA-02 SS-JFC) [35]

Meteorological satellites currently have microwave sensors that utilize the above bands such as the NOAA 16 satellite carrying the ATOVS Advanced Microwave Sounding Unit (AMSU)-A and AMSU-B radiometers operating in selected bands from near 23 to above 183-GHz , especially at 23.8, 31.5, 50.3, 55, 89, 157, and 183 [89-92, 146-148]. Separately, the issue of ozone and O_2 monitoring is relevant, and we refer to Fig. 20 for utilizing the broad 60 GHz peak according to the US standard atmosphere – absorption model of Liebe [110-112], 1993

Follow-on systems with other capabilities and spectrum needs are imminent, such as the Advanced Microwave Scanning Radiometer (AMSR)-E radiometer on NASA's AQUA satellite that will include channels from 6.9 to 89 GHz. Japan, India, China, Russia and Europe (EUMETSAT) also plan to use passive microwave remote sensing soon. The Conical-scanning Microwave Imager/Sounder (CMIS) under development by NPOESS will utilize frequencies

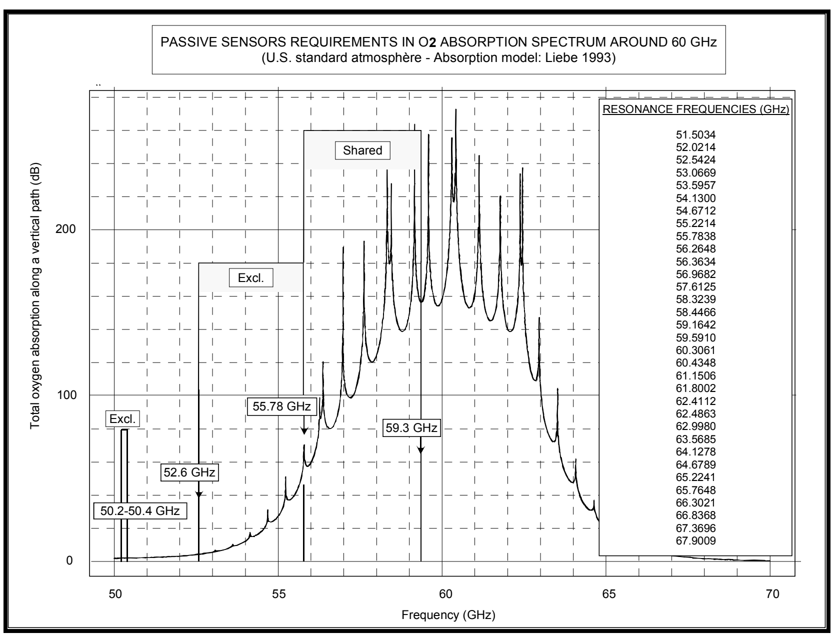


Fig. 20: O_2 absorption spectrum along a vertical path around 60 GHz (multiple absorption lines) for the passive sensor requirements (according to the US standard atmosphere – absorption model by Liebe, 1993) [110-112, 115]

from near 6 to above 183 GHz by 2009 and special attention was given during development of the CMIS design to minimize the utilization of unprotected spectrum and thus limit the level of Radio Frequency Interference (RFI). Very considerable efforts are paid toward the RFI mitigation, especially for future radiometric space SAR systems.

d) Remote Sensing Satellites

Table 4: Compatibility studies by frequency band and satellite sensor type

Frequency band (MHz)	Sensor Type				
	SAR	**Altimeter**	**Scatterometer**	**Precipitation Radars**	**Cloud profile radars**
430-440	(F)				
1215-1300	SIR-C, JERS-1, PALSAR (ALOS)				
3100-3300	ALMAZ	RA2 (F)			
5150-5250	RADARSAT-2 (F)	JASON (F)			
5250-5350	RADARSAT, ASAR, ERS1/2, ENVISAT ASAR (F)	TOPEX	ERS1/2, NSCAT (F), METOP ASCAT (F)		
5350-5470	RADARSAT-2 (F)	JASON (F)			
8550-8650	(P)	(P)	(P)		
9500-9800	X-SAR, Okean-O SLR	(P)	(P)		
9975-10025					
13250-13400		JASON	NSCAT, SEAWINDS	TRMM follow-on (F)	
13400-13750		JASON, ERS1/2	NSCAT, SEAWINDS, ENVISAT RA-2 (F)	TRMM follow-on (F)	
17200-17300			(P)	(P)	
24050-24250				(P)	
35500-35600		(P)	(P)	TRMM follow-on (F)	
78000-79000					(P)
94000-94100					CLOUDSAT (F)
133500-134000					(P)
237900-238000					(P)
Note: (F) Future Proposed, (P) Postulated, and Currently Operating otherwise					

Table 5: Allocation status for active space-borne sensors

Frequency band (GHz)	User objectives	Allocation status	Allocation needed	Users
0.420-0.470	Forest monitoring (biomass)	None	Primary or secondary, minimum 6 MHz	P-band SAR
1.215-1.300	Wave structure, geology, soil moisture, interfe-rometry (DEM)	Primary No.**5.332**, **5.333**, **5.335**	Primary	L-band SAR (JERS-1, SIR-C, PALSAR)
3.1-3.3	Geology	Secondary	Primary	S-band SAR, Altimeter (Envisat RA-2 second freq)
5.15-5.25	Geology, ocean-ography, sea ice, land use, inter-ferometry. (DEM)	None	Primary	High resolution radar altimeters (Jason)
5.25-5.46	Geology, ocean-ography, sea ice, land use, inter-ferometry. (DEM)	Primary No.**5.447D**, **5.448A, B**	Primary 5460-5570 MHz	SAR, scatterometers, altimeters (AMI, ASCAT, ASAR, ALT/dual, IKAR-N)
8.55-8.65	High resolution SAR applications (tactical) plus snow and ice	Primary No.**5.463**	Primary	Not identified
9.5-9.8	High resolution SAR applications (tactical) plus snow and ice	Primary No.**5.476A**	Primary	X-band SAR, Okean-O SLR
9.975-10.025	High resolution SAR applications (tactical) plus snow and ice	Secondary No.**5.479**	Not identified	Not identified
13.25-13.75	Wind, ice, geoid	Primary No.**5.498A**, **501A**, **B**	Primary	Ku-band scatterometers, altimeters (NSCAT, ALT/dual, PR, R225, IKAR-D&N, RA, RA-2, DPR)
17.2-17.3	Vegetation, snow, rain, wind	Primary No.**5.513A**		Rain radars Precipitation radar, scatterometers
24.05-24.25	Rain	Secondary	Primary	Rain radars Precipitation radar (IKAR-D&N)
35.5-36.0	Ice, wind, geoid, snow	Primary No.**5.551A**		Altimeters, scatterometers Precipitation radar

Frequency band (GHz)	User objectives	Allocation status	Allocation needed	Users
				(IKAR-N,DPR)
78-79	Altimetry (land and ice) at high spatial resolution	Primary No.**5.560**		Radio altimeters
94.0-94.1	Cloud profiling	Primary No.**5.562**	Primary	Cloud profile radars (ESA CPR, CPR/NASA, IKAR-D&N)
133500-134000	Cloud profiling	Primary No.**5.562E**		Cloud profile radars
237900-238000	Cloud profiling	Primary No.**5.563B**		Cloud profile radars

4. Communications and Telecommunications Needs of the Free Terrestrial – Space Propagation – Space versus the Transmission through Interference-Safe Optic-Fiber Networks

The ever-increasing inter & trans-communications sector requires more and more spectral bands, which differ from one ITU region to the other (see Fig. 21); and open-propagation-space mobile UWB audio & video communications is only in its infant stage. These rapidly expanding techniques are all active devices, and strongly pollute the open propagation environment and they pose the foremost and most devastating interference sources

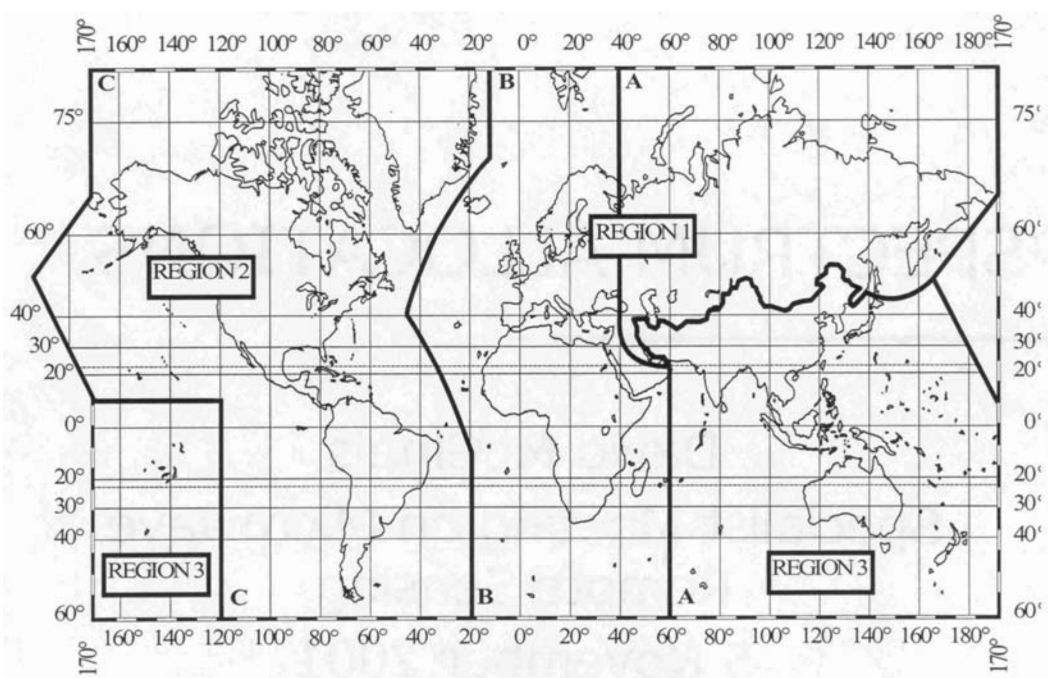


Fig. 21: ITU Regions defined by the ITU/WMO

for any passive as well as active remote sensing system at ground, in air and space. Because the ongoing aggressive expansionism of the International Communications Complex is irreversible, we – the active and passive remote sensing community – must insist that "***What-ever can be transmitted via Interference-Safe Optic-Fibers must be removed from the propagation environment".*** For existing and new 'terrestrial-space tele-communication links', the accruing interference must be reduced to the absolute minimum. Mobile & Cell audio/video-communication pose a most critical threat, and must be removed where-ever possible from polluting the open electromagnetic propagation environment, and these differ widely for and within the designated ITU Regions, which are defined in Fig. 21 .

Ultra-Wide-Band (UWB) devices are also being contemplated as unlicensed, largely unregulated devices in the United States and elsewhere. Some potential uses of these devices are in the areas of communications, tracking and radars. Communications applications are expected to include: in-building communications systems, indoor broadband cellular phones, private radios, and wireless broadband Internet access. Examples of precision tracking applications include personnel and asset tracking for increased security, aviation ground tracking and position-based commerce capabilities. Radar applications of UWB technology include: through-wall imaging radar, security systems, collision avoidance sensors for cars and boats and other precision measurement devices.

UWB technology supports radio frequency devices quite dissimilar to conventional emitters. Rather than having the majority of their energy concentrated within the allocated bandwidth, these devices operate at percentage bandwidths of 25 to 100 percent of the center frequency. As such, the energy is distributed across a very wide range of spectrum and can thus be a potential interference source to many different types of incumbent users operating in spectrum far removed from the UWB center frequency. Although claimed by its proponents to cause no more interference than other unlicensed FCC "Part 15" devices, a great deal of concern currently exists as to the overall electromagnetic compatibility of these devices with other existing spectrum users. This concern is amplified when aggregate interference potential of large numbers of such devices is considered. The potential for interference to a large number of passive remote sensing frequency bands is quite real according to various studies done to date. This interference potential will be examined in detail.

Certainly, there exists a justifiable need to accommodate properly communication links in the open free propagation environment, but such systems must then be designed to enable straightforward RFI reduction techniques to be implemented.

5. The Expansion of GPS and Surveillance Sensor Satellite Fleets and its RF Security Threat Interference [30, 77, 84, 85, 100, 101, 104, 106, 134, also see pertinent web sites]

Modern transportation and defense surveillance plus environmental stress-change monitoring will depend increasingly more on permanently deployed space-fleets of GPS and POL-IN-SAR satellite clusters. Any and all interference must be reduced to its minimum.

According to the newest guidelines available (sse Volpe DOT –R&D-Center web-sites):
GPS satellites transmit two microwave carrier signals. The L1 frequency (1575.42 MHz) carries the navigation message and the Standard Positioning Service (SPS) code signals. This is the

normal civilian GPS signal. The L2 frequency (1227.60 MHz) is used to measure the ionospheric delay by Precise Positioning Service (PPS) equipped receivers, typically defense users.

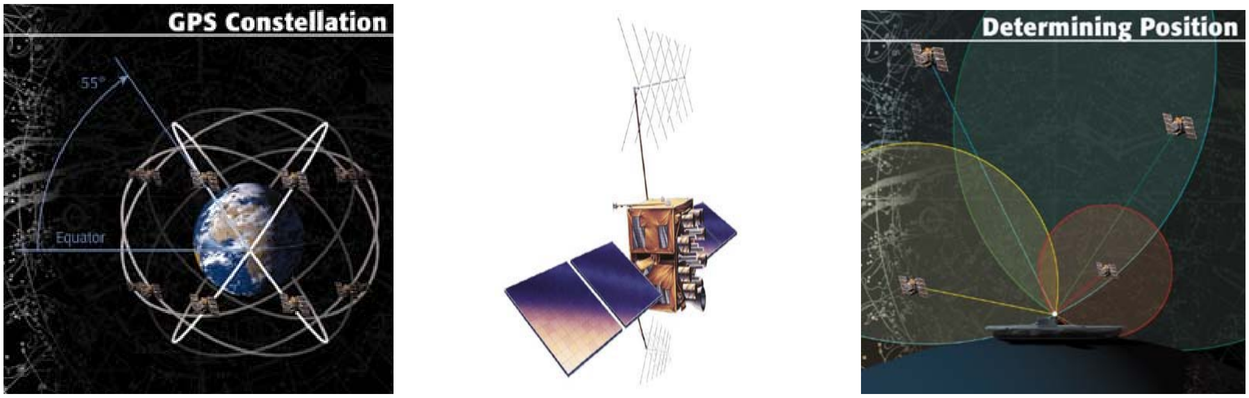


Fig. 22: The NAVSTAR Global Positioning System (www.spacecom.af.mil/usspace/gps.htm)

Three binary codes are transmitted on the L1 and/or L2 carrier phases.

- The C/A Code (Coarse Acquisition) modulates the L1 carrier phase. The C/A code is a repeating 1 MHz Pseudo Random Noise (PRN) Code. This noise-like code modulates the L1 carrier signal, "spreading" the spectrum over a 1 MHz bandwidth. The C/A code repeats every 1023 bits (one millisecond). There is a different C/A code PRN for each SV. GPS satellites are often identified by their PRN number, the unique identifier for each pseudo-random-noise code. The C/A code that modulates the L1 carrier is the basis for the civil SPS.
- The P-Code (Precise) modulates both the L1 and L2 carrier phases. The P-Code is a very long (seven days) 10 MHz PRN code. In the Anti-Spoofing (AS) mode of operation, the P-Code is encrypted into the Y-Code. The encrypted Y-Code requires a classified AS Module for each receiver channel and is for use only by authorized users with cryptographic keys. The P (Y)-Code is the basis for the PPS.
- The Navigation Message also modulates the L1-C/A code signal. The Navigation Message is a 50 Hz signal consisting of data bits that describe the GPS satellite orbits, clock corrections, and other system parameters.

There have been several recent developments, which deserve mentioning:

- The Selective Availability degradation of the civilian (C/A) codes has been turned off and now the SPS is, in theory, as accurate as the PPS. However, the wider band width and 7 day repeat cycle of the P-code should provide better accuracy in the presence of noise or outside interference.
- The Anti-Spoofing is an encryption of the P-code to mitigate the chance that someone could transmit a fake GPS signal that tricks a GPS unit into computing an erroneous position. Both the encryption technique and the proper P-codes are needed to deceive the unwary user.
- A possible new GPS frequency, L5 @ 1176.45 MHz, has been proposed; which is currently being applied for to the ITU/WMO.

a) Expansion of the existing US GPS versus the Russian-Federation GLONASS, and the Introduction of the European-Union GNSS Global Navigation Satellite System

The ever expanding civilization and with it increase in transportation and surveying techniques demands even higher accuracy and resolution of the currently operated GPS system, which in turn requires an increase of the number of equidistantly orbiting GPS-Satellites. On top of it, the Russian Federation, the European Union, and most likely the Asian countries desire to operate their own system, which increases the number of orbiting RFI sources, yet every possible means of reducing RF propagation noise and RF interference must be achieved. These GPS and other space-operated navigation system pose the greatest threat to radio-astronomy with its space-oriented large radar dishes. Therefore, every effort ought to be made not to let GLONASS the GNISS nor any other similar system be developed, but have efforts joined for the benefit of keeping our *"Sacred Treasure – **the Natural Electromagnetic Spectrum (NES)**"* less polluted by cutting down on unnecessary duplication But maybe, radio-astronomy is more fortunate, and could - *in the foreseeable not so distant future* - have its huge antenna systems placed beyond the orbital belt of the nadir-looking GPS and Remote Sensing Satellites or even on the back-side of the moon, then maybe protected from most terrestrial RFI sources. This is an option not available to the close-to-nadir remote sensing of the terrestrial covers [see pertinent web sites].

b) Introduction of permanent fleets of equidistantly orbiting POL-IN-SAR Satellites & Clusters: US High-Tech21, EU Cart-wheel, etc. [10, 36, 87, 95 – 97, 118 – 123, 127 – 130]

Currently, there are only a relatively low number of passive and especially only very few active remote sensing satellites in space. This situation will be changing very rapidly, and the advent of clusters of active remote sensing satellites such as the US HighTechSat21 and the EU Cart-wheel, albeit currently only at the less interesting X-Band, active/passive SAR clusters are to be launched shortly. The permanently orbiting fleets of equi-distantly orbiting high-resolution POL-IN-SAR systems, guaranteeing hourly monitoring of each place on Earth, is not only being contemplated any longer, but are completing the design phase; and again every possible step of reducing RF interference to its absolute minimum must become a major goal of these missions.

c) RF Security Threat Mitigation

With the launching and continual safe operation of the fleets of the Communication Satellite Clusters, the GPS and the Remote Sensing Satellite Clusters, an entirely new threat for safeguarding information, for uninterrupted operation, and for mitigating intentional jamming must be devised for the active sensors, and more so for the passive sensors, which are by far more vulnerable to intentional full-power jamming. Conversely, the camouflaging of terrestrial sites by local RF noise and intentional interference poses another threat to the monitoring of terrestrial surface properties and its stress changes from air and space; and counter-measures need also be developed for civil applications. Here, defense counter-measure and counter-counter-measure technology must be adopted and applied to the civil sector; and some of the pertinent well known and novel techniques are summarized in the next Section.

6. Technical Means of Radio-Frequency Interference Signal Reduction and Radio-Frequency Security Threat Mitigation for both Active and Passive Sensors

Various spectral-band-dependent algorithms were developed for pertinent RF-Interference reduction, which require now to be optimized to their ultimate performance levels. These

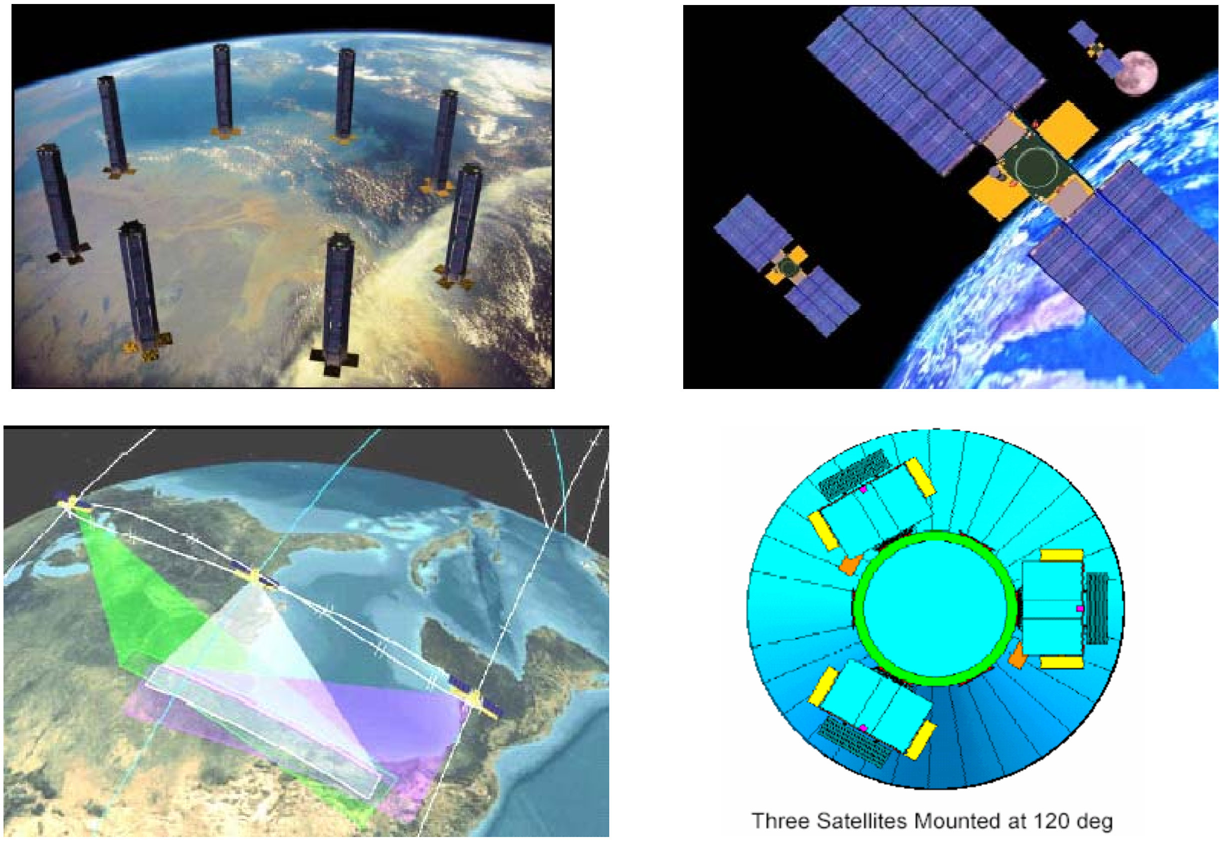


Fig 23: The US HighTech21Bistatic X-Band Space-SAR Configuration, top-left: multi-satellite configuration; top-right: three-satellite configuration; bottom-left: SAR-Interferometry; bottom-right: three-satellite packaging

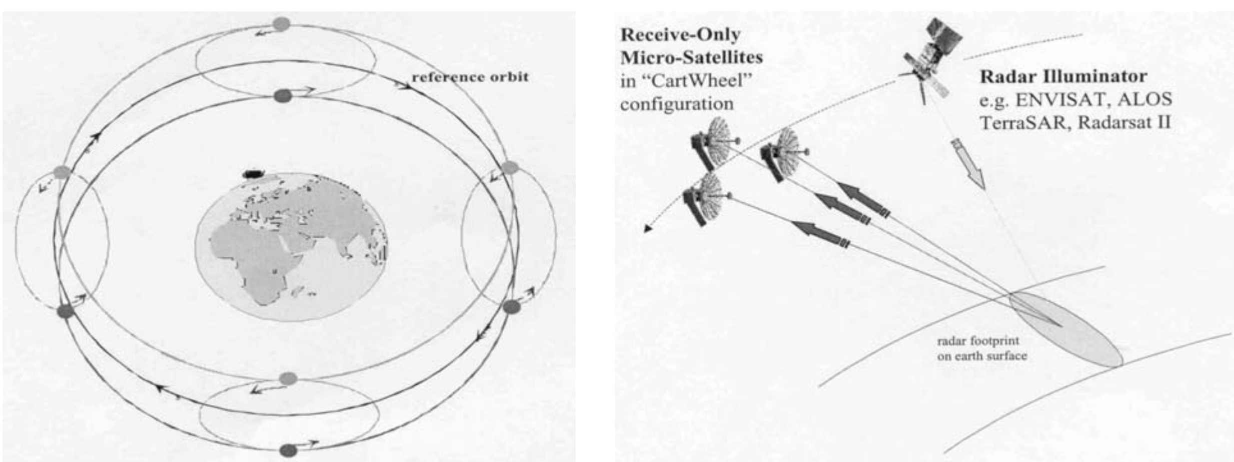


Fig 24: The EU Cart-Wheel Configurations, left: two-satellite cart-wheel formation; right: bi-static interferometric SAR

techniques make use, in principle, of polarimetric angle of arrival techniques applicable to both Passive versus Active Sensor considerations. Although technological aspects play a very major role and are of paramount importance; because of severe time & space constraints, it was not possible to address these vital issues here, and the references provided will have to suffice.

Whereas RFI reduction and mitigation techniques for passive remote sensing systems were first developed in radio astronomy and ULF/ELF aeronomy, the VHF/UHF/EHV, microwave & millimeter-wave passive remote sensing community is now catching up very fast. For active remote sensing, great progress was made by the defense radar community, and major RFI Reduction techniques, which reside within the open literature, deserve to be summarized and cited here. In the following RFI reduction and RF Security Threat mitigation techniques are reviewed separately for the major spectral bands.

a) ULF/ELF

For both active & passive beyond the horizon long-range submersible ranging and detection the naval radio research community developed rather sophisticated large array systems, which deserve attention. Of major concern are the higher order 50/60 Hz harmonics of AC electric power transmission und appliances, etc. [37 – 41].

For passive aeronomic natural background-emission-source sensing, the magnetic and goniometric techniques, for example used for *'seismo-genic signature analysis'* are trend-setting innovations. These methods are based on polarimetric angle-of-arrival sensor-array techniques and are utilizing geophysical modeling approaches, which are in desperate need of perfection. There exists by now a wide body of pertinent literature; and we refer here especially to the three Workshop Proceedings of 1994,1999 and 2002 edited by Hayakawa that were dedicated to these problems.

b) VHF/UHF [6 – 8, 53, 62, 74 – 76, 98, 137, 142, 162, 169]

Major RFI reduction and mitigation technology in this wide spectral domain was developed by the defense radar experts (ArtTech House, see web site); and those are again based on the polarimetric angle-of-arrival (POL-AOA) techniques with implementation of synthetic aperture arrays of commutating single antennas within the array along the line of motion (LOM). The most effective ones are listed and are briefly described, and the most often implemented in the case of air-borne and space-borne SAR systems are underlined, and then compared here [142]:

CAF (Cross Ambiguity Function): The CAF is a generalization of the Cross-Correlation Function of Detection and Communications Theory, and it is used in combination of the DD & TDOA methods, requiring three or more baselines, which may be undesirable but fool-prove if available.

DD (Differential Doppler): The Doppler frequency difference of arrival, or Differential Doppler (DD), method uses Doppler frequency instead of time history, and was developed primarily in sonar, and is used in nature by marine mammals as well as by bats. There exists a profuse literature on these principles, which intrinsically make use of the HPFT method. We note that neither the TDOA nor the DD methods yield unique solutions when applied by themselves, and they need to be used in combination together with CAF.

FDOA (Frequency Difference of Arrival): It is based on the utilization of Doppler Frequency (DF) Difference of Arrival rather than the Time of Arrival (TOA) or TDOA. While subject to the same detrimental shortcomings as simple intereferometers or DD and Doppler Frequency techniques, especially when operated close to ground, where multi-path interference becomes dominant, both the TDOA & FDOA in combination with DD have demonstrated to achieve reliable accuracy. This is howevewr accomplished at the expense of time, which seems not to be the case for the IDFM or IDFS methods, peddled along by Baghdady [6, 7].

IDFM (Induced Direction-dependent Frequency Modulation): This represents an alternative method to IDFS, and like it, makes use of virtually commuted lines of antennas in order to *'null out'* the direction of the interfering emitter.

HPFT (Hyperbolic Position Fixing Technique): When the time-of –arrival (TOA), the time difference of arrival (TDOA) and/or the frequency difference of arrival (FDOA), or the differential Doppler (DD) by another appellation, measured at two or more widely dispersed and moving sensors are used to geo-locate emitters/jammers, then QUADRATIC CURVES are involved. Generally, the intersection of the resulting curves denotes the emitter location. In oder for these to be frequency-differences caused by movement, either the sensor (one or more) and/or the target must be in motion. Therefore such sensor system apply usually to air-borne and space-bone systems; as described in detail in Poisel (2002) [142].

IDFS (Induced Doppler Frequency Shift): was developed primarily by Baghdady [6, 7] for separating co-channel signals incident at different angles of arrival (AOAs). The IDFS technique is based on a method of processing a multiplicity of signals sharing the same time, frequency, spatial and polarization space in a way such as to convert their AOA differences to frequency differences sufficient to enable the receiver array to select individual signals and reject other undesired signals. It ranks high if not superior to among all other direction finding mechanisms, and it is ideally suited for multiple aspect angle RFI suppression in that it makes use of wide-banding and band-spreading frequency modulation by cos (AOA) by electronically moving virtually a single frequency or a finite set of those. However, IDFS relies on a line-array of antennas *only to define a path of motion* for synthesizing the output of a *single moving antenna element*, and hence a local reference for AOA. Furthermore it can be applied to distinguishing isolated sources of interference within a cluster of such, and thus becomes also very attractive to RF Security Threat Signal mitigation. .

PDI (Phase Difference Interferometry): Like IDFS, PDI is based on different mechanisms and associated laws governing performance in resolution and sensitivity/vulnerability to additive co-channel noise and interference/jamming. PDI is based on propagation phase-shift versus cos(AOA); and it relies on a line-array of antenna-elements *only to define an aperture* or synthesizing *static spatial effects associated with aperture dimensions*. Whereas for IDFS the number of interspacing between array elements are set by requirements of *discrete-time sampling of a hypothetically moving antenna position versus time;* for the PDI the interspacing between the outermost elements defines the desired aperture, and the spacing between intermediate pairs of elements is set by requirements of resolving the ambiguity in the phase difference between the outermost elements.

TOA (Time of Arrival): The arrival time of a signal of two or more dispersed sensors can be used to estimate the the geographic location of the emitting entity (ies). Various methods and techniques were first explored in artillery and also in tectonic-stress release-source (earthquake) detection, and methods are well established.

TDOA (Time Difference of Arrival): The TDOA method makes use of the HPFT technique and it is commonly used in conjunction with the DD method.

Comparison:

- IDFS trades bandwidth of induced FM by Doppler for cos (AOA) resolution and immunity to co-channel noise anfd interference;

- PDI trades baseline length (aperture) for cos (AOA) resolution and accuracy against AWGN, but offers no resistance to co-channel & on-frequency interference/jamming.

- Among the non-commutated Antenna-array systems, the TDOA and/or FDAO techniques in combination with DD seem to work best provided the sensors are in motion, high above ground so that multi-path effects can be minimized.

In concluding this section, it should be mentioned that a great many additional applicable methods not found in the open literature exist; and that the pertinent texts published by Artech House (see web sites) seem to provide the best source of information; and especially the new text by Poisel [142]

c) Microwave and Millimeter-wave RFI Reduction in Radio-Astronomy & Atmospheric Radiometry: NOAA-ETL, Gasiewski et al [56 – 59, 89 – 92, 99]

In radio astronomy [136, 26, 27, 126] the problem of efficient RFI reduction is of paramount priority for its passive sensor systems as well as radio-astronomic radars. During the forth-coming URSI-GA-02 in Maastricht, NL, 2002 August 17 – 24 a Special Invited Joint Session of URSI-INT-JFC on the subject of *"Frequency Allocation, RF Interference Reduction, and RF Security Threat Mitigation"* is taking place on Thursday, 2002 August 22, in which the leading experts of the Radio Astronomy Community are summarizing their newest approaches. Based on the recent contributions of the speakers, a brief summary with references will soon become available on the URSI-GA-02 web-site [86].

More so, very considerable advances had been accomplished in the passive space remote sensing of atmospheric trace gases with the implementation of highly improved Polarimetric Radiometric Sensors as is being pursued so vigorously by Drs. Dave Kunkee and Al Gasiewski [56 – 59, 99] with their able collaborators at NOAA-ETL (see pertinent entry to NOAA-ETL web-sites).

7. Economic Considerations and Proposals for Footing the Bill of Implementing and Maintaining the "*World Natural Heritage Electromagnetic Quit Sites*", and of Safeguarding the *"Natural Electromagnetic Spectrum*" as a *"Sanctioned Natural Resource and Treasure*"

One of the major obstacles of cleaning up and more efficiently utilizing the ***"Natural Electromagnetic Spectrum (NES)***" - *a sacredly to be treasured natural resource of global importance* – is the cost factor. Because of the fact that little revenue has accrued hitherto from environmental remote sensing utilization of the **"Natural Electromagnetic Spectrum"** in comparison to the truly exorbitant reap-off for commercial uses; in the past into the presence, either very timid or no attempts what-so-ever were made by the **"Global Remote Sensing Community"** for protecting the turf on behalf of our sacred **"Natural Electromagnetic Spectrum";** and, especially its foremost user-mission for protecting the *' Health of the Earth's Covers'.*

Obviously, there exist some very basic priorities for allocating frequency bands – narrow and wide – which must stay fixed, such as the regulatory for defense and security and operational bands for air, water and ground navigation. It is anticipated that with a reorganized approach for regulating the distribution of frequency bands, these vital demands could even be strengthened.

It is estimated that the commercial income per frequency/second-of-transmission is of the order of - say USD 10 (100) M$ or even more – and with the current over-expansion of mobile (handy) and cell-phone communications & video transmission the applicable factor will even drastically rise higher. And, unless the ***"Global Remote Sensing Community***" is not putting up a fierce and highly coordinated fight, we will be squeezed out; and the health of Planet Earth may whither away, and all the greedy expansionism of the "*International Telecommunications Complex*" might one day resolve in a catastrophic collapse. Therefore, we – the **"International Remote Sensing Community"** ought to request that the commercial users be levied with a - ***say 5% to 10% or even higher surcharge*** – solely to be applied to safeguarding the purity – as far as is physically required - of the "**Natural Electromagnetic Spectrum"** by providing funds for developing the pertinent **"Remote Sensing & Monitoring Ground-based, Air/Space-borne Sensor Systems",** which must include the establishment of **"World Natural Electromagnetic Quiet Sites**", and also for operating and maintaining them. In other words there has to be a fair distribution of the revenues gained from using ***"NES",*** similar to levying toll-charges and gasoline tax for designing, building and maintaining clean motorways, etc.; there should be charges introduced for utilizing the " National and International Information Highways as well as excessive mobile communications, etc. **.**

Furthermore, the telecommunications industry is to explore digital technologies which enable a drastic cut in the require bandwidth and number of bands. The remote sensing electronics experts have proven beyond any doubt that by fully utilizing polarization information not only for POL-IN-SAR remote sensing but also in terrestrial-space tele-communications will provide substantial increases in the proper information transmission, and certainly so the implementation of novel advanced digital communications techniques. Yes, it is costly at first, but the income exists, and now need to be properly re-distributed, and applied correctly.

In summary, there does not exist any good reason in the world why we – the **Internationl Remote Sensing Community** – should not initiate **the Fight of the Twenty-first Century** in requesting that we be given the resources and means of fulfilling our sacred duties of being the "*Environmental Pathologists and Radiologists of Planet Earth"* for securing the geo-environmental health of the Terrestrial Covers: ***"Let us not slumber along any longer, but let's get going and request what is due and not for greedy reasons or for packing our pockets with virtual gold - fool's gold – unfortunately it would mainly be jibber-ish on the air-waves".***

8. Conclusions: Quest for Complete Reorganization of Frequency Band Allocation and Distribution for Reducing Colliding Demands of Increasing Number of Users

Every effort must be made to guarantee that mankind is protecting the **"Natural Unperturbed-by-man Electromagnetic Spectrum"** as a ***"Natural Treasure***", which must be safeguarded against the greedy misuse of the International Communication Complex. In order to fulfill this request, a finite set of isolated "***World Heritage Natural Electromagnetic Quiet Sites***" needs to be identified, so designate, licensed by UNESCO and protected by the UNITED NATIONS.

Some would take a less pessimistic view of the future for spectrum conservation. For example in the excellent little book, **"Radio Spectrum Conservation**" by William Gosling, Newnes publishers, 2000 [62], the great spectral inefficiency of current communication techniques are spelled out, but it is demonstrated how digital technology will lead to much improved use of the spectrum. A concrete example is DAB (digital audio broadcasting) in place of the very inefficient FM radio, and so on. Even more archaic frequency band misuses exist that are deplorable, known but not further listed here.

Passive & Active Remote Sensing must be given MUCH HIGHER PRIORITY; anything not requiring the open propagation space must be removed; and the Telecommunications Complex must be forced to work hard in reducing their reliance on the increase of designated spectral bands for their commercial use, in fact must be enticed/forced to reduce their electromagnetic spectral real-estate by many factors with the focused implementation of efficient digital techniques of spectral bandwidth reduction. The passive & active Remote Sensing community must adopt the high professional stature of being the pathologists and radiologists of the terrestrial and also the planetary environment, and nothing less.

Much improved RFI reduction and mitigation methods must rapidly be advanced because of the increasing needs of an expanding civilization. This may imply the introduction of standardized signal coding techniques and time-sharing for the use of identical spectral bands.

Any information transmission not requiring open propagation space must be relegated to the non-interfering continental and transcontinental optical fiber networks, which provide anyhow much more bandwidth and security; and on top of it are highly under-used. This indeed presents a very serious issue considering the huge amounts that were invested in setting up this enormous global EO fiber network that is at the brink of collapse because of being under-used, and not because we don't need it, but because of irrational turf-battles.

ULF/ELF polarimetric radiometry needs to be paired with Infrasonic [67] & Near-infrasonic Surface Pressure Imaging [11-15] for impulsive shock-type catastrophe detection and source identification for effective short-term disaster mitigation, and not only for secretive purposes for the detection of mega-ton explosions.

Some ‘consensus’ ought to be found among competing forces to retain only one Space-borne Electronic Satellite Navigation System. Since the US GPS is far more developed than the Russian Federation GLONASS , the EU GNSS (Galileo), and any other Indian or Asian system on the drawing boards; only the GPS System ought to be retained, however providing access to most of the previously encrypted systems. Sooner or later we need to place GPS under the United Nations, but under US guidance, supervision and maintenance.

Radio-astronomic observatories ought to be moved outside the space-remote-sensing orbital ellipsoid; to the backside of the moon for example; into outer terrestrial orbital space for reducing damage to their extremely sensitive sensor systems. Certainly, earth-observing close-to-nadir remote sensing of the terrestrial environment do not have such *an’ easy way out’!*

The EO-RF signature transducer field-sensor technology need to be rapidly advanced [170] and applied to the entire spectrum of users including infrastructure household device technology, industry and tele-communication plus sensor technology in order to cut down on RF noise emission on the one hand, and on interference on the other.

This EO-RF $LiNbO_3$ transducer technology when paired with highly improved digital signal/image processing technology should provide the novel technological means to revamp the current almost archaic misuse of the **“Natural Electromagnetic Spectrum *(NES*)”** most decisively. No time must be lost in advancing these technologies; and once achieved a most desired clean-up of the e-m spectrum can be realized together with establishment of fixed relatively broadband windows, spread logarithmically across the entire spectrum and for the protection of distinct natural frequency resonances vital for the accurate and permanent remote sensing of the e-m environment of the terrestrial covers. .

In fact, any misuse of the sacred **“Natural Electromagnetic Spectrum *(NES)”*** ought to be punished by stiff fines; and the intentional and/or careless generation of propagation litter along the *“International Information Highway”* ought to be dealt with similar to fining the ruthless production of refuse litter along our National, State and Local Highways in the US and elsewhere.

By using radar polarimetry [18- 25, 31 – 34, 113, 114, 131, 132, 143, 161, 163, 164, 172 -177], we can help mitigate the need for wider bandwidth. Take for example single frequency polarimetric interferometry, which can be used for vegetation height mapping whereas the other method is GeoSAR, which needs at least two frequencies and considerable bandwidth. We would conclude that polarimetry studies are very important in trying to secure the highest information extraction per hertz. This fact has been proven beyond doubt, and it should be emphasized as an important area of research, because most radar or even SAR systems still in use are non-polarimetric, or of single often undefined antenna polarization states. .

In every respect more attention ought to be paid toward educating the general public about the serious state of pollution of the natural electromagnetic spectrum, and especially in the education of our educational systems K12 to Post-Doctoral levels – all inclusive – about reducing the undesirable propagation litter! It seems that our youth and also the population in general has absolute no comprehension of these serious matters, and indeed great need exists for across the board Ki2 to adult education.

8. Acknowledgments

This research would have not been undertaken, had we not all benefited from the ingenious *ONR-IFU-NICOP* program, the *EC-TMR* and various other International programs that fostered a deeper understanding of the natural background characteristics of the ***NES***, and of safeguarding its purity. Special thanks are herewith extended to Otto Kessler, Jim S. Verdi, Bill Stachnik, Sam Ghaleb, Patrick Serna, Ed Westwater, and many more of those who kindly encouraged our research studies within NATO and the US-DOD and NOAA. A special note of thanks is extended to Mrs. Helen E. Coffey, for providing most useful information and data from the NOAA Space Environment Center in Boulder, CO.

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During the preparation of this manuscript one of great luminaries of precision magneto-metric monitoring, Dr. Arthur W, (Bill) Green from the USGS-GRSF in Golden, CO departed from us. Although never engaged directly in seismo-genic earthquake precursor studies, he – a renowned magnetologist - was and became a strong supporter and in Fig. 4a, the Diagram he proposed, herewith designated the **"*Bill-Green-Diagram*"**, is included to his honor [63 – 66].

Here, we also thank the organizing committee for inviting us for presenting this exposition during the URSI, Int'l Commission F, Open Symposium on *"Propagation and Remote Sensing*", and especially to Dr. Madhukar Chandra, Mr. Archibald, and Mrs. Birgit Wilhelm for their invitation and assistance.

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Some but not all web sites pertinent to this exposition:

United Nations: ITU-WMO web sites
ITU (International Telecommunication Union: http://www.itu.int/
WMO (The World Meteorological Organization): http://www.wmo.ch/
US-DOC-NTIA-Manual (Regulations & Procedures for Federal Radio Frequency Management): http://www.ntia.doc.gov/oshome/redbook/redbook.html.
UN-WMO-Hndbook: http://wmo.ch/web/www/TEM/SG-RFC/Handbook.html (Chapt. 5, Part 1)

GPS Satellite Systems
US Coast Guard: http://www.navcen.uscg.gov
US DOT/Volpe Center GPS Activities: http://www.volpe.dot.gov/gps/index.html
GPS World Magazine: http://www.gpsworld.com
GLONASS: http://www.rssi.ru/SFCSIC/english.html
GNSS: http://www.esa.int/export/esaSA/navigation.html

RFI Reduction & RFI Security Threat Mitigation
Artech House: http://www.artech-house.com/
GPS: http://www.volpe.dot.gov/gps/index.html

Solar-Terrestrial Noise Prediction and Solar wind estimates
NOAA-NGDC SOHO (Solar & Heliospheric Observatory): http://sohowww.nascom.nasa.gov
NASA-JPL/JHU-APL, ACE (Advanced Composition Explorer): http://www.srl.caltech.edu/ACE or http://sd-www.jhuapl.edu/ACE/ACE_FactSheet.html
List of Solar Observatories:http://www.ngdc.noaa.gov/stp/SOLAR/IAUWGdoc.html) from the Whole Sun Catalog at http://arthemis.na.astro.it/wsc/

RAS-SB-ISC-SSRT : http://www.eastsib.ru/~ssrt

ITU/WMO Earth Exploration Satellite Services (EESS):
http://www.itu.int/newsarchive/press/WRC97/agenda.html
SA.515 Frequency bands and bandwidths used for satellite passive sensing
SA.1028 Performance criteria for satellite passive remote sensing
SA.1029 Interference criteria for satellite passive remote sensing

Passive Millimeter and Sub-millimeter Space Sensors:
AMSR: http://adeos2.hq.nasda.go.jp/
AMSR-E: http://eos-pm.gsfc.nasa.gov/
SMILES: http://smiles.tksc.nasda.go.jp

Active Millimeter and Sub-millimeter Space Sensors:
SAR: http://www.jpl.nasa.gov/radar/sircxsar/dsea.html
PALSAR/ALOS: http://www.eorc.nasda.go.jp/ALOS
Altimeter: http://ibis.grdl.noaa.gov/SAT/near_rt/enso/topex_97.html
NSCAT: http://winds.jpl.nasa.gov/nscat_data/
TRMM: http://pequod.jpl.nasa.gov/armarsim.html
Cloudsat: http://pequod.jpl.nasa.gov/armar.html
SLR: http://sputnik1.infospace.ru ; http://planet.iitp.ru

POL-SAR Microwave Imaging Background:
IGARSS: http://www.igarss.org
IEEE-AESS-Radar Systems Panel: http://www.aeroconf.org
URSI-GA-02: http://www.ursi-ga2002.nl/
NASA-JPL AIRSAR: http://airsar.jpl.nasa.gov or http://southport.jpl.nasa.gov
ESA-CEOS: http://www.estec.esa.nl/CONFANNOUN/99b02
EU-SAR: http://www.fhr.fgan.de/eusar/
ASAR: http://www.space.gc.ca/home/index.asp

Airborne POL-IN-SAR Imaging Platforms
GEOSAR: http://southport.jpl.nasa.gov
AIR-SAR: airsar.jpl.nasa.gov
ERIM-SARS: www.erim-int.com
E-SAR: www.dlr.de/NE-HF/projects/ESAR ,
AEROSENSING: http://www.op.dlr.de/aerosensing
PI-SAR: www.crl.go.jp
EMISAR: www.dcrs.dk/DCRS
RAMSES: www.onera.fr/english.html
CARABAS: www.foa.se/eng/carabas.html
PHARUS: neonet.nlr.nl/tno-fel
HUTRAD: www.space.hut.fi

Spaceborne POL-IN-SAR Imaging Platforms
SIR-C/X-SAR: http://www.jpl.nasa.gov/radar/sircxsar/dsea.html

SRTM: www-radar.jpl.nasa.gov/srtm/index.html
SRTM-DLR: www.dlr.de/NEHF/projects/SRTM
RADARSAT: www.ccrs.nrcan.gc.ca/globesar2
ERS-1/2: earth1.esrin.esa.it/ERS/
JERS-1: www.eoc.nasda.go.jp
ENVISAT-1: envisat.estec.esa.nl/
ADEOS: www.nasda.go.jp/index_e.html
COMMERCIAL: www.spaceimaging.com
PALSAR/ALOS: http://www.eorc.nasda.go.jp/ALOS
TERRASAR : http://www.infoterra-global.com/terrasar.html

Spaceborne Bistatic IN-SAR Clusters
HighTech SAR21: http://www-aig.jpl.nasa.gov/public/planning/asc/ ;
http://www.aria.cec.wustl.edu/SSC01/papers/1-3.pdf ; http://www.vs.afrl.af.mil/Demos/
Three Corner SAT: http://www-aig.jpl.nasa.gov/public/planning/3cs/
Cartwheel: http://www.estec.esa.nl/conferences/99b02/index.html

Hyperspectral Optical Imaging Platforms
JPL AVIRIS: makalu.jpl.nasa.gov/aviris.html
GSFC: ltpwww.gsfc.nasa.gov/ltp/ltp_projects.html
VCL: essp.gsfc.nasa.gov/vcl/
SLICER: ltpwww.gsfc.nasa.gov/eib/slicer.html
EO-1: eo1.gsfc.nasa.gov/
ASAS: asas.gsfc.nasa.gov/asashome.html
NASA-MASTER: http://masterweb.jpl.nasa.gov
NASA-MODIS&ASTER: http://ltpwww.gsfc.nasa.gov/MODIS/MAS
USA-AS-MI-LAB, REDSTONE ARSENAL: http://www.tec.army.mil

Infrasonic Atmospheric Pressure Sensing
NOAA-IAPS: http://www4.etl.noaa.gov/infra/infrasonic.html