Mapping of Microwave radiation associated with propagating High Energy Particles in the Atmosphere

Leonid V. Sorokin

Economic & Mathematical modeling Department,
Peoples' Friendship University of Russia,
Moscow, Russia

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If it Possible?

- High Energy Particles propagate through the atmosphere.
- High Energy Particles produces ionisation channels in the air.
- High Energy Particles can provoke electrical breakdown in the cloud.
- High Energy Particles can be accelerated in the electric field.
- Bremsstrahlung.
- Microwave radiation was observed on the different stages of lightning development.

To Do List

- Mapping the sources of Microwave radiation during the thunderstorm.
- Comparison of the Microwave radiation during the fair weather and thunderstorm activity.
- What High Energy Particles could produce the Microwave radiation?
- What intensity of the Microwave radiation from High Energy Particles with different energies?
- What altitude of emitting the Microwave radiation?

Research objectives

- Microwave mapping of the High Energy Particles propagation through the atmosphere.
- Microwave mapping of the High Energy Particles trajectories in the clouds.
- Looking for the sources of Microwave radiation during the fair weather and thunderstorm activity.
- Mapping of electrical discharges and location the charged layers inside the cloud.
- Comparison of the Microwave mapping with the data Aragats Sky Monitoring - Cosmic Ray Division.

Previous research

- Bremsstrahlung.
- Microwave radiation from the the atmosphere and thunderstorm activity.
- Laboratory Spark Discharge.
- Wireless communication system Interference.
- New Mexico Tech Lightning Mapping Array (LMA).

Bremsstrahlung

Electron transition between two continuous energy states with initial and final energies radiates an emitted quantum (Bekefi, et. al., 1961).

- Bekefi, G.,and S. C. Brown, 1961: Emission of radio-frequencywaves from plasmas, J. Appl. Phys. 32, 25.

Radio Frequency radiation from lightning at frequencies higher than 500 MHz associated with stepped leaders and dart leaders (Takagi et. al. 1963).

- Takagi, M., T. Takeuti, 1963: Atmospheric radiation from lightning discharges, Proc. Res. Inst. Atmos. Nagoya Univ., 10, 1–11.
- Brook, M., and N. Kitagawa, 1964: Radiation from lightning discharges in the frequency range 400 to 1000 Mc/s, J. Geophys. Res., 69(12), 2431–2434, doi:10.1029/JZ069i012p02431.

Bremsstrahlung process is a possible source of RF emissions in UHF and microwaves (Rai, et. al., 1972).

- Rai, J., R. Manoranjan and B. A. P. Tantry, 1972: Bremsstrählung as a Possible Source of UHF Emissions from Lightning, Nature Physical Science 238, 59-60.

"RF bursts of radiation during the preliminary breakdown, in conjunction with the initial return stroke and during dart leaders of subsequent strokes" (Rust, et. al., 1979)

- Rust, W. D., P. R. Krehbiel, and A. Shalanta, 1979: Measurements of radiation from lightning at 2200 MHz, Geophys. Res. Lett., 6(2), 85–88.

2.4 GHz

- The first investigation on the ffects of interference from natural lightning flashes on wireless communication links at 2.4 GHz was done by M.R. Ahmad et. al. (2011) on the paper:
- M.R. Ahmad, M. Rashid, M.H.A. Aziz, M.M. Esa, V. Cooray, M. Rahman, E. Dutkiewicz, Analysis of lightning-induced transient in 2.4 GHz wireless communication system, in: Proc. of IEEE International Conference on Space Science and Communication (IconSpace), Penang, Malaysia, July 12–13, 2011, pp. 225–230.

2.4 GHz NBPs

- Microwave radiation at 2.4 GHz associated with cloud (IC) flash events such as narrow bipolar pulses (NBPs) were observed in the M.R. Ahmad et. all. (2013) research:
- M.R. Ahmad, M.R.M. Esa, V. Cooray, Narrow bipolar pulses and associated microwave radiation, in: Proc. of Progress In Electromagnetics Research Symposium (PIERS), Stockholm, Sweden, August 12–15, 2013, pp. 1087–1090.

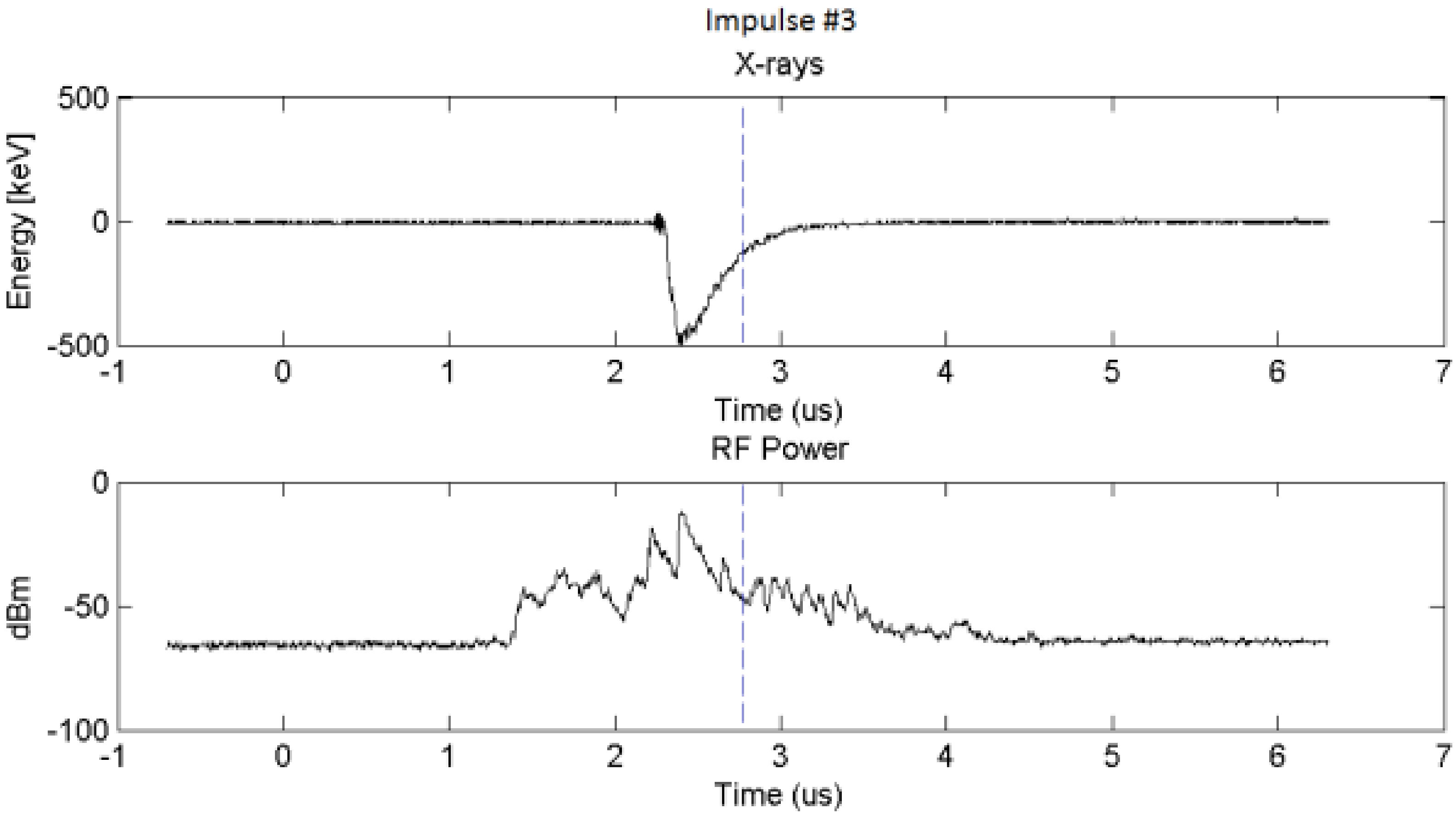
Wireless communication system operating at 2.4 GHz

- Mohd Riduan Ahmada, Mona Riza Mohd Esaa, Vernon Cooraya, Eryk Dutkiewiczd. Interference from cloud-to-ground and cloud flashes in wireless communication system / http://dx.doi.org/10.1016/j.epsr.2014.03.022

Laboratory Spark Discharge

- Joan Montanyà, Ferran Fabró, Víctor March, Oscar van der Velde, Glòria Solà, David Romero. X-rays and microwave RF power from high voltage laboratory sparks / XV International Conference on Atmospheric Electricity, 15-20 June 2014, Norman, Oklahoma, U.S.A. pp. 1-6.
- Montanyà et al. (2015), X-rays and microwave RF power from high voltage laboratory sparks, Journal of Atmospheric and Solar-Terrestrial Physics, http://dx.doi.org/10.1016/j.jastp.2015.06.009

X-rays and RF power at 2.4 GHz



- X-rays and RF power at 2.4 GHz for negative voltage impulse. Plot corresponds to a voltage impulse of -775 kV. Vertical dashed line indicates the breakdown time (Montanyà, et. al. 2014).

dBm - volts - watts conversion (50 ohm)

dBm	V	Po
+50	70.7V	100W
+40	22.5V	10W
+30	7.10V	1W
+20	2.25V	100mW
+10	0.71V	10mW
0	0.225V	1mW
-10	0.071V	0.1mW
-20	22.5mV	0.01mW
-30	7.1mV	0.001mW
-40	2.25mV	0.1μW
-50	0.71mV	0.01μW
-60	0.225mV	0.001μW
-70	71μV	0.1nW
-80	22.5μV	0.01nW
-90	7.1μV	0.001nW
-100	2.25μV	0.1pW
-110	710nV	0.01pW
-120	225nV	0.001pW

1.63 GHz

- The observation of strong microwave radiation at 1.63 GHz (bandwidth 2 MHz) associated with cloud-to-ground (CG) flash events such as preliminary breakdown process (PBP), stepped leaders (SLs), dart leaders (DLs), and return strokes (RSs) was done in the paper:
- D. Petersen, W. Beasley, Microwave radio emissions of negative cloud-toground lightning flashes, Atmos. Res. 135–136 (2014) 314–321.

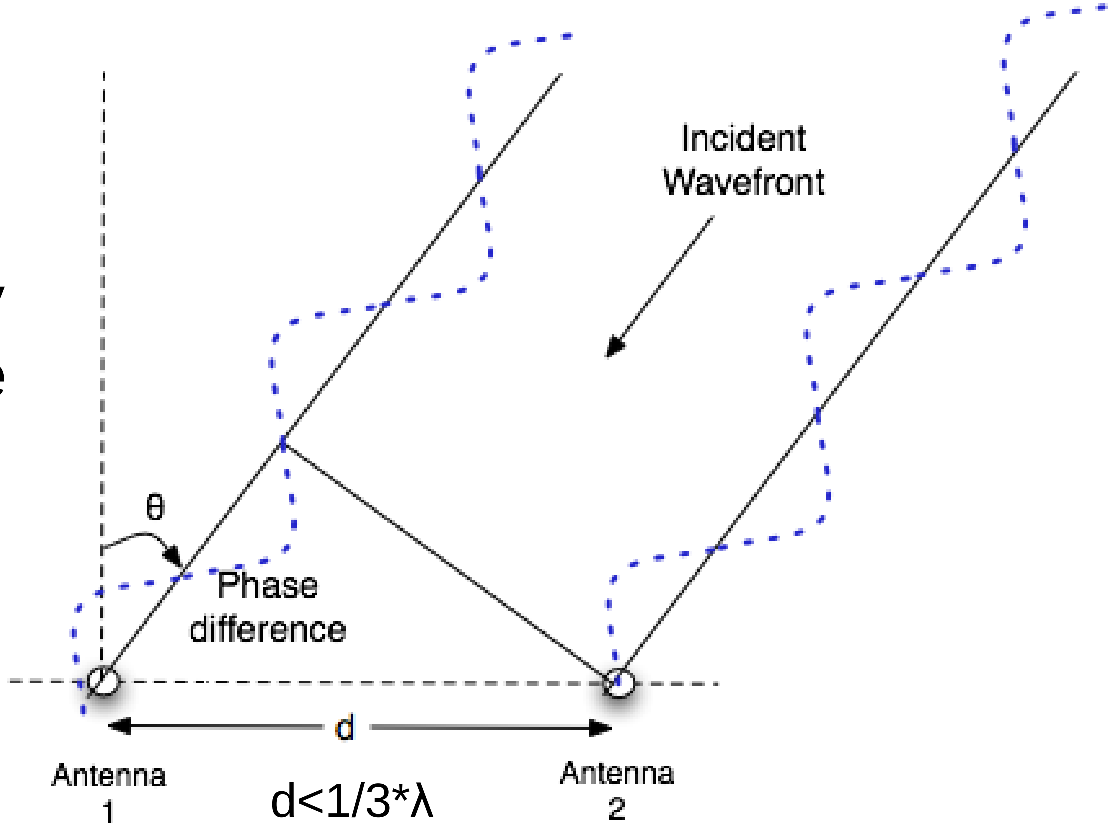
Space Time Localization

- Radio Direction Finding
- Phase Methods
- Time Methods
- Triangulation

Phase Methods

- Phase interferometry
- Correlative interferometer
- Precise analog electronics

It is very difficult to apply the Phase Method to the mono pulse signal.



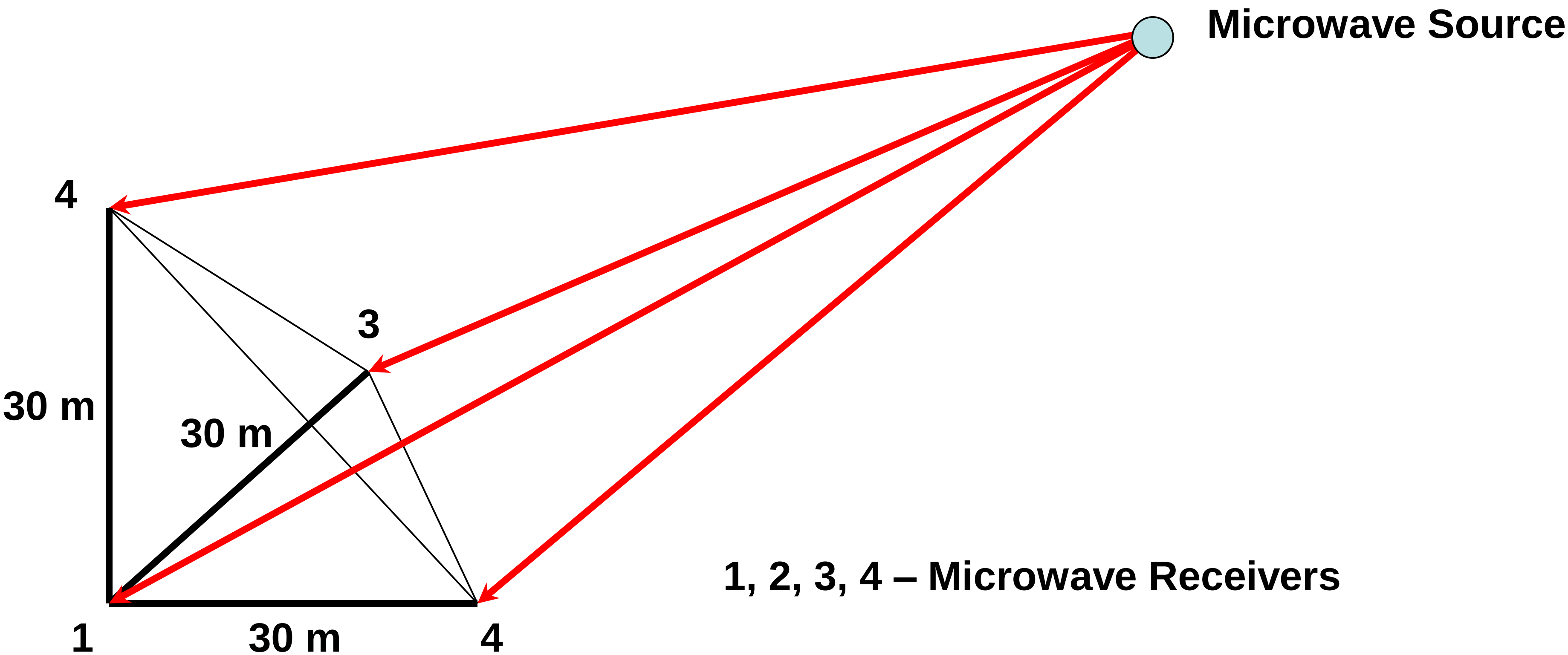
$d<1/3*\lambda$

Time Methods

- Time of Arrival (ToA)
- Time Difference of Arrival (TDoA)
- Angle of Arrival (AoA) determines the direction by measuring the TDoA at the elements of the antenna array.
- Precise time synchronization of the signal receivers (~1 ns).
- Low cost digital transmission lines.

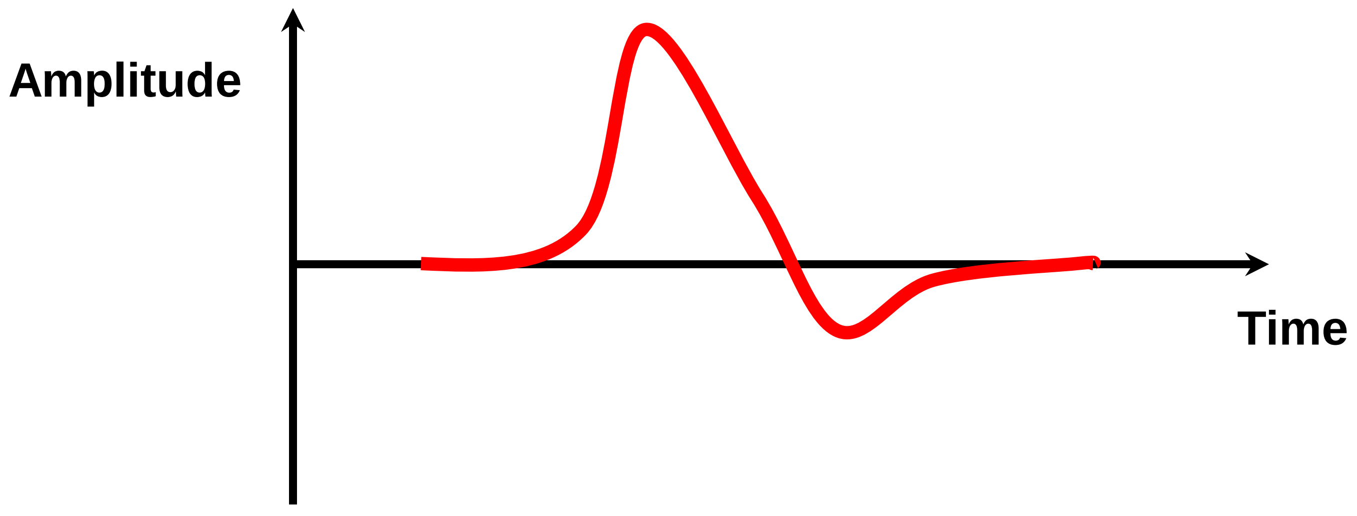
Triangulation

- Triangulation – “is the process of determining the location of a source point by forming triangles to it from known points”.

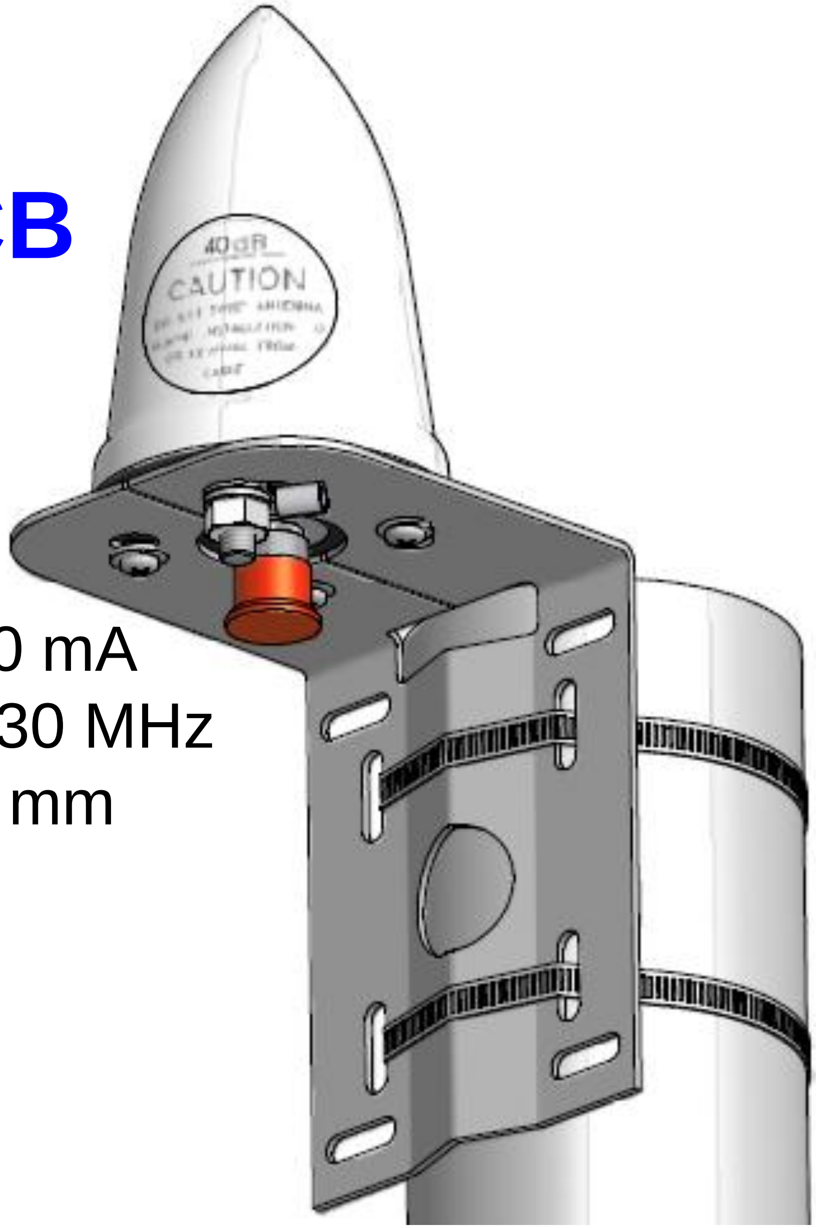


Mono Pulse Signal

- Duration ~ 1 ns
- Rise Time ~ 100 ps
- Repetition Rate ~ 10 ns
- Signal Frequency Band = 1-10 GHz



Antenna
GPSGL-TMG-SPI-40NCB

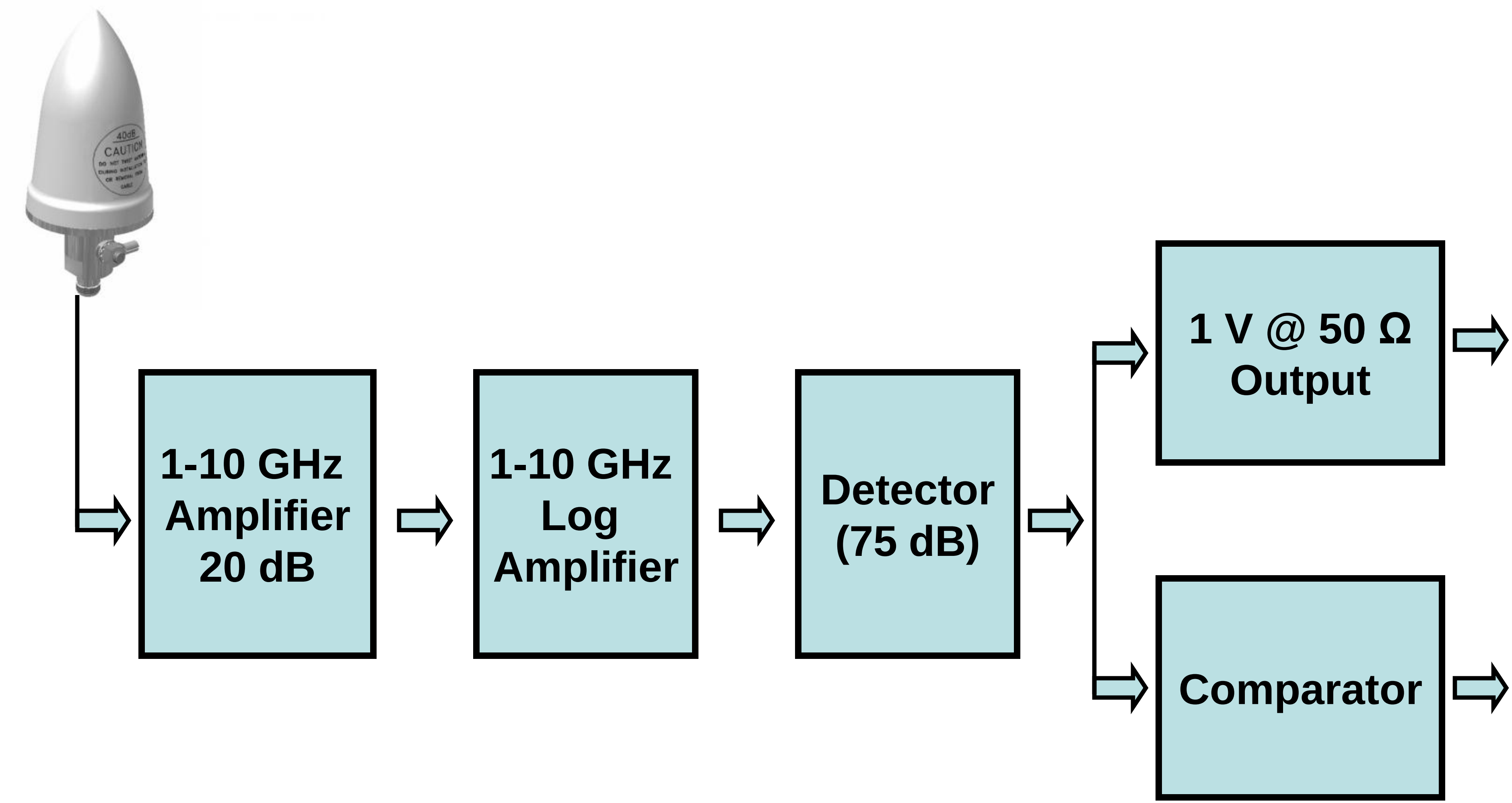


- GLONASS/GPS/GALILEO band
- Power supply: from 3.3 V to 9 V, 40 mA
- Antenna Frequency Band = 1590±30 MHz
- Antenna Wave Length = 188.7±36 mm
- Amplification:
  38±4 dB GLONASS L1
  40±4 dB GPS L1/GALILEO E1
- Rejection filter:
  -60 dB @ 1530 MHz
  -60 dB @ 1660 MHz
- Lightning protection: 90 V, 20 kA

Microwave Propagation Time

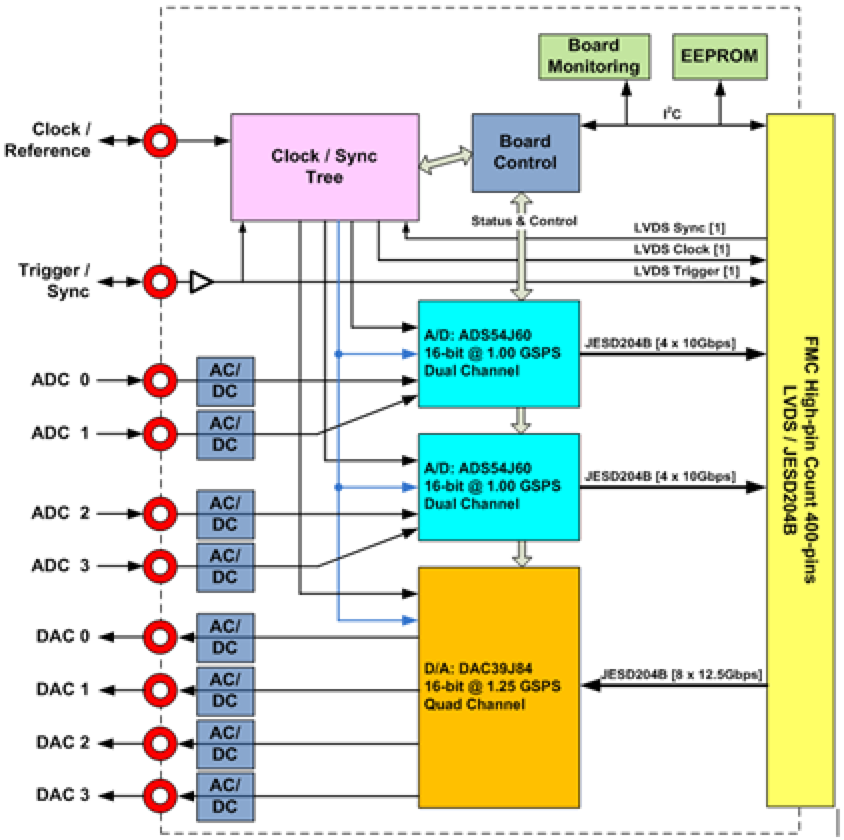
Propagation Time	Distanse
10 μs	3 km
1 μs	300 m
100 ns	30 m
10 ns	3 m
1 ns	0.3 m
100 ps	0.03 m

Microwave Pulse Receiver



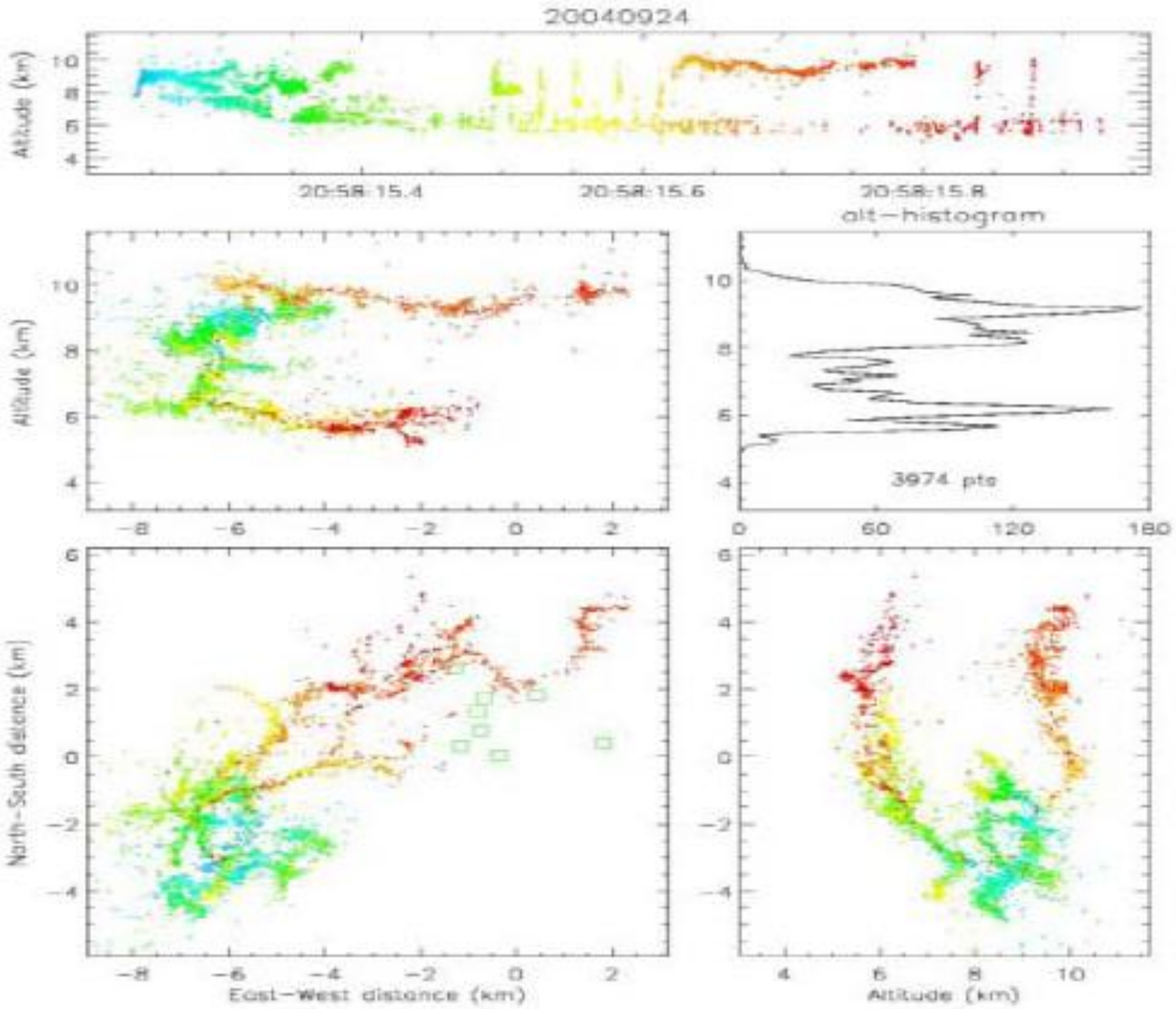
- Total Gain 135 dB

For Digital Signal Processing FMC120



- Quad Channel 16-bit A/D @ 1 GSPS
- Quad Channel 16-bit D/A @ 1.25 GSPS
- Simultaneous sampling on all channels up to 1 GSPS
- RADAR/SONAR Electronic Warfare

New Mexico Tech Lightning Mapping Array (LMA)



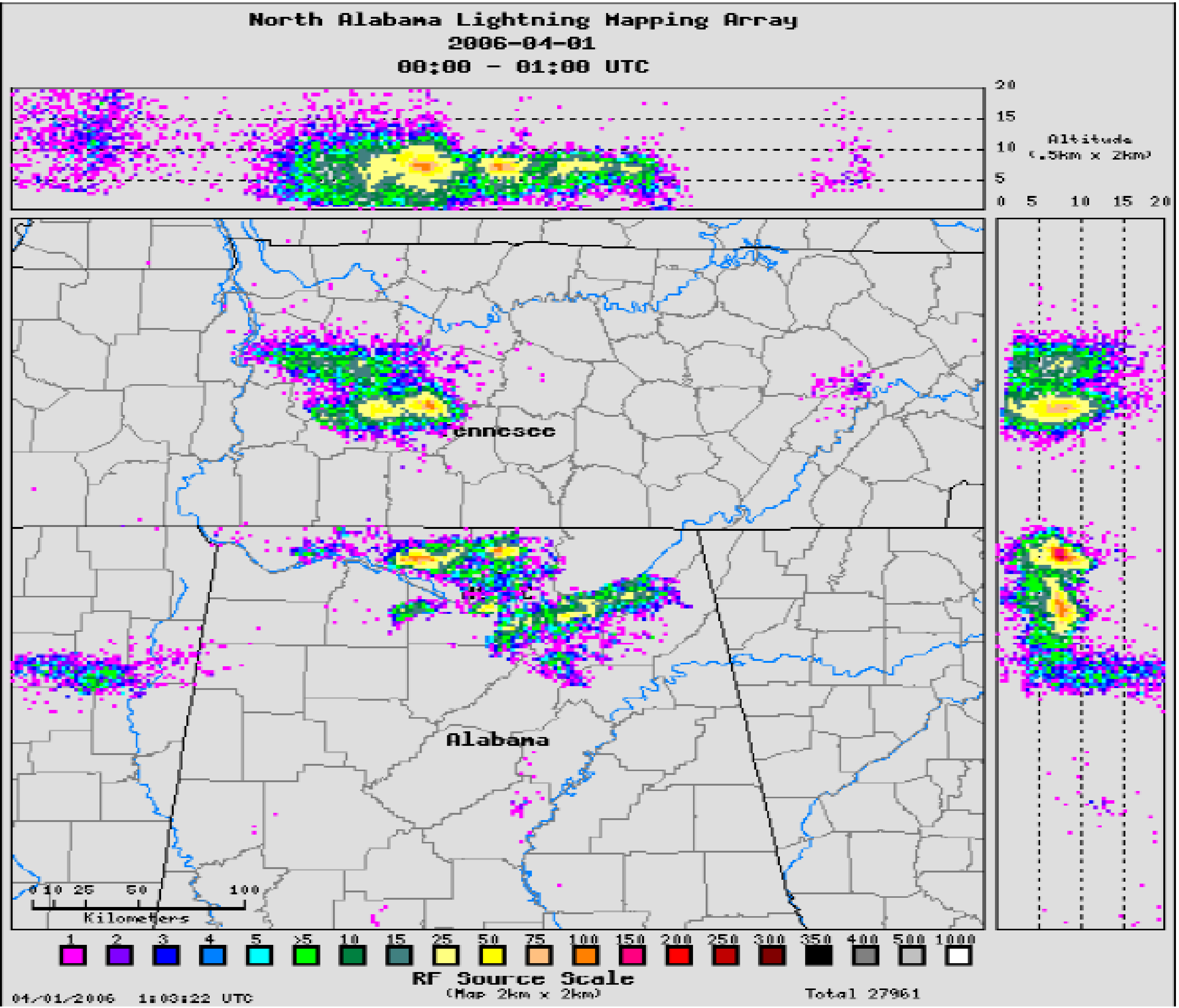
Uses a network of 12 television receivers tuned to 66 MHz.

Lightning radio pulses are correlated in time between stations.

Images intracloud (IC) flashes

Courtesy to:
Richard Sonnenfeld
Physics Department & Langmuir Laboratory for Atmospheric Physics
New Mexico Institute of Mining and Technology

North Alabama Lightning Mapping Array



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New Mexico Institute of Mining and Technology


Aragats Cosmic Ray Research Station
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106 м
2007
Дата съемки: 12.25.2015
40°28'18.74" С
44°10'55.74" В
Высота над уровнем моря: 3198 м
Google


E 44°15'54"
Armenia Nor Amberd
N40°22'30"
72 м
© 2016 Google
Image © 2016 DigitalGlobe
© 2016 Basarsoft
Google
2015
Дата съемки: 12.25.2015 40°22'30.61" С 44°15'51.29" В Высота над уровнем моря: 1974 м

Conclusion

- The powerful radio-physical methods of Microwave radiation sources passive direction-finding are highly effective fore mapping High Energy Particles beams.
- This instrument can be used for obtaining time and spatial information on the propagating High Energy Particles in the Atmosphere together with particle detectors and facilities of A. Alikhanyan National Lab (Yerevan Physics Institute).
- The visualization of the High Energy Particles beams can be useful fore studying the high-energy physics in the atmosphere: Thunderstorm ground Enhancements (TGEs), Relativistic Ranaway Electron Avalanches (RREAs), Extensive air showers, Terrestrial Gamma-ray Flashes (TGFs) and propagation of High Energy Particles from Space and Solar.