UNDERGROUND & UNDERWATER COMMUNICATION

ECE 516E – ANTENNA & RADIOWAVE PROPAGATION

Monday, 12 January 2026

SITUATIONS REQUIRING UNDERGROUND & UNDERWATER COMMUNICATION

1. Underground transport

2. Underground Mines
3. Submarines

4. Underwater Divers

ADVANTAGES OF UNDERGROUND COMMUNICATION

The main advantage of underground communication is that it is not affected by:

1. Industrial interference
2. Atmospheric interference
3. Storms
4. Hurricanes

DESIGNATION & GENERAL USES OF RADIO SPECTRUM

ACRONYM	FULL DESIGNATOR	FREQUENCY RANGE	APPLICATIONS
ULF	Ultra-low Frequencies	3-30Hz	Navy Strategic Communication
ELF	Extremely Low Frequencies	30 – 300 Hz	
VF	Voice Frequencies	300 – 3000 Hz	
VLF	Very Low Frequencies	3 – 30 KHz	Navy Strategic Communication
LF	Low Frequencies	30 – 300 KHz	Navy Communication, Navigation
MF	Medium Frequency	300 – 3000 KHz	Navigation, AM Broadcasting
HF	High Frequency	3 – 30 MHz	Short wave radio, Ham radio
VHF	Very Hugh Frequencies	30 – 300 MHz	FM radio, TV , Police/Fire Service
UHF	Ultra High Frequencies	300 – 3000 MHz	Cellular Communication, TV, Satellite, Radar, WiFi, Blue tooth
SHF	Super High Frequency	3 – 30 GHz	Satellite, Radar, WiMax
EHF	Extremely High Frequencies	20 – 300 GHz	Satellite Communication

DESIGNATION OF RADIO FREQUENCIES – COMMUNICATIONS AUTHORITY
http://www.ca.go.ke

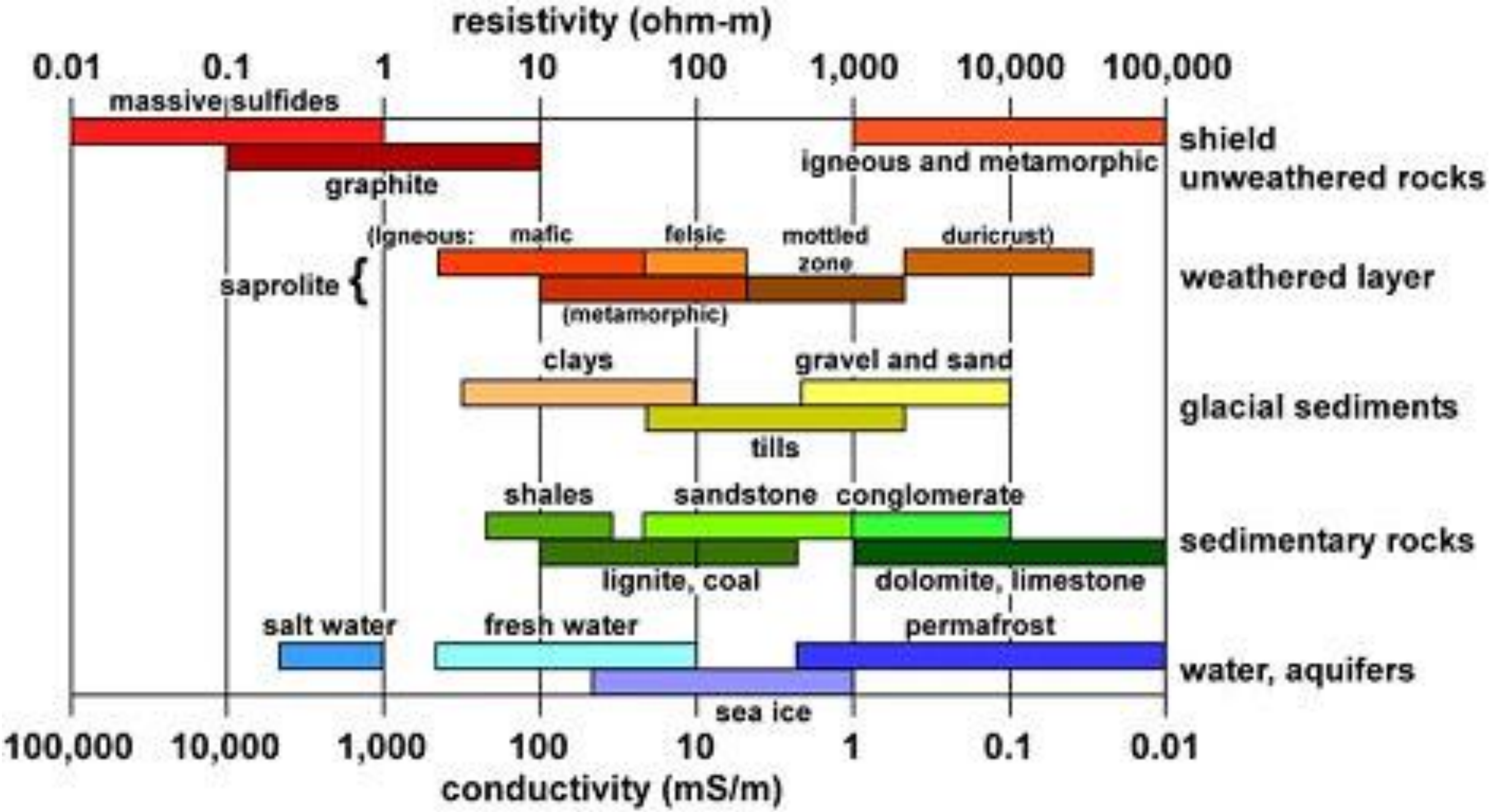
1.4. NOMENCLATURE OF FREQUENCY BANDS (COMMUNICATION AUTHORITY)

1. VLF (Very Low Frequency) : 3 to 30 KHz
2. LF (Low Frequency) : 30 to 300 KHz
3. MF (Medium Frequency) : 300 to 3000 KHz
4. HF (High Frequency): 3 to 30 MHz
5. VHF (Very High Frequency) : 30 to 300 MHz
6. UHF (Ultra High Frequency) : 300 to 3000 MHz
7. SHF (Super High Frequency) : 3 to 30 GHz
8. EHF (Extra High Frequency) : 30 to 300 GHz

EFECT OF EARTH'S CRUST & SEA WATER

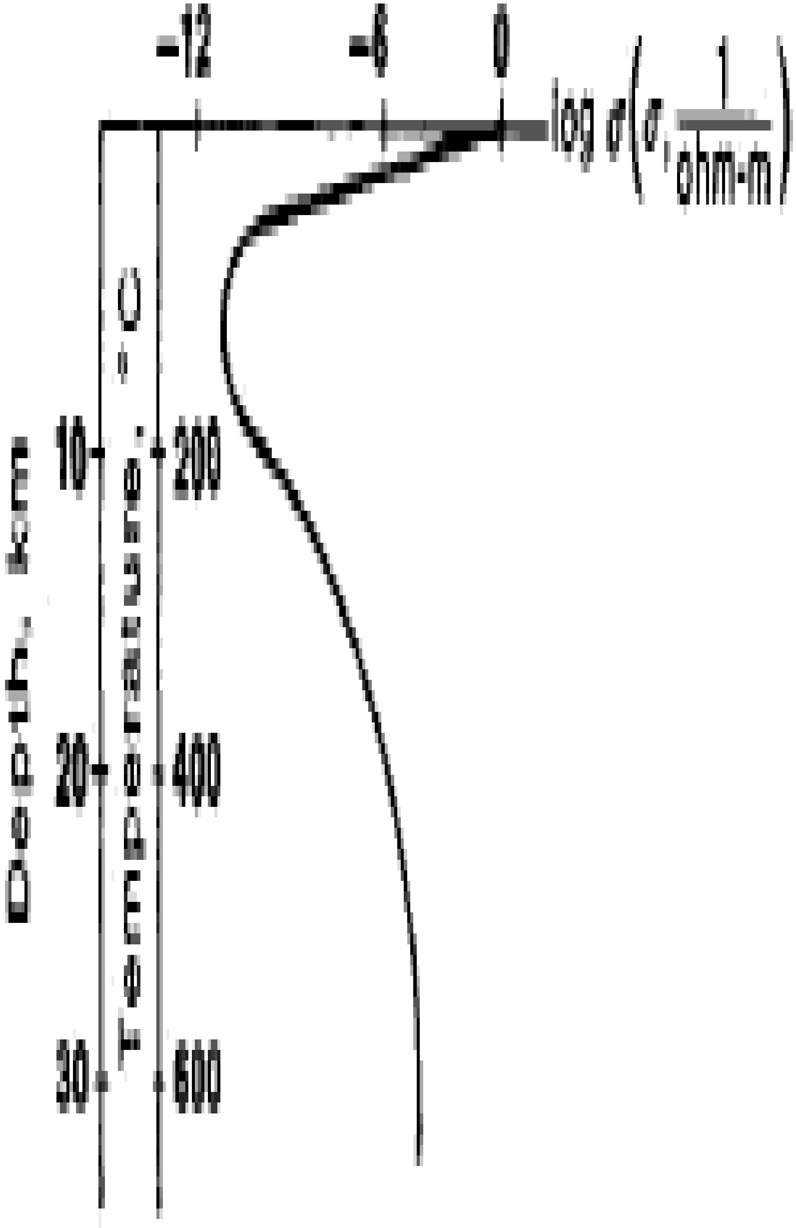
1. The earth's crust and sea water have electrical conductivity σ and strongly absorb radio waves.
2. For sedimentary rocks in the surface layer of the earth's crust, $\sigma \approx 10^{-3}$–10^{-2} (ohm-m)$^{-1}$.
3. In such media, a wave is practically damped out at distances greater than a few wavelengths.
4. The absorption coefficient increases with frequency.
5. Therefore, only frequencies less than 300 kHz are used for underground radio communication.

CONDUCTIVITIES OF VARIOUS MATERIALS



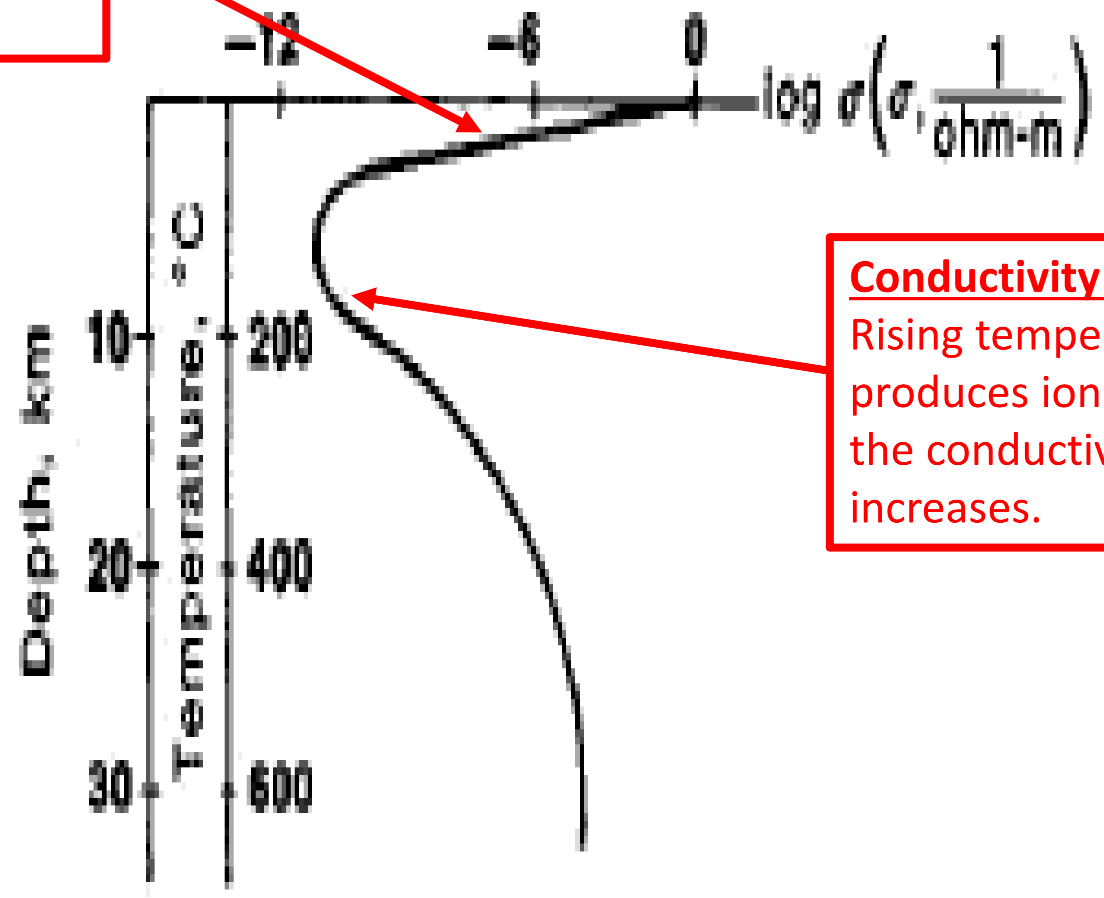
VARIATION OF CONDUCTIVITY WITH DEPTH/1

- **As the depth increases**, conductivity reduces due to the presence of hard rocks such as granites, gneisses and basalts.
- The rocks have lower conductivity compared with those on the surface.
- At depths of 3 to 7 km, σ may be reduced to 10^{-11} (ohm-m)-1.
- **With a further increase in depth**, the rising temperature produces ionization (an inverted ionosphere), and conductivity starts increasing.
- **Further deep**, the rising temperature produces ionization (sometimes called inverted ionosphere), and the conductivity increases to higher levels.



VARIATION OF CONDUCTIVITY WITH DEPTH/2

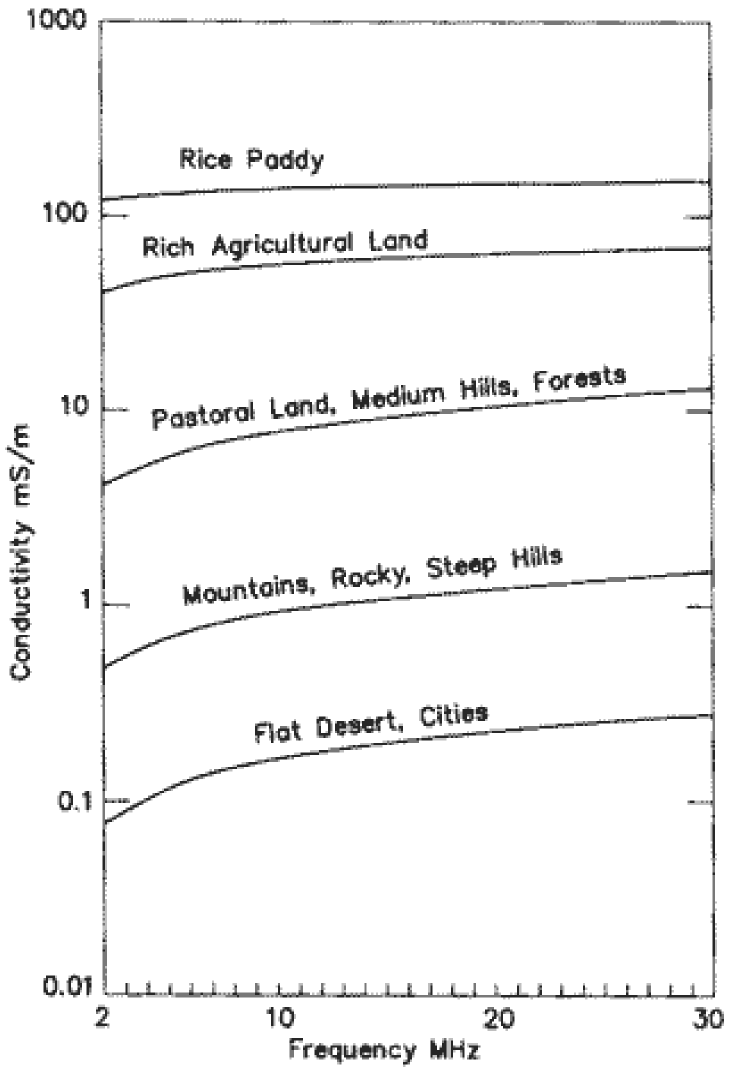
Conductivity reduces
The presence of hard rocks such as granites, gneisses and basalts lowers conductivity



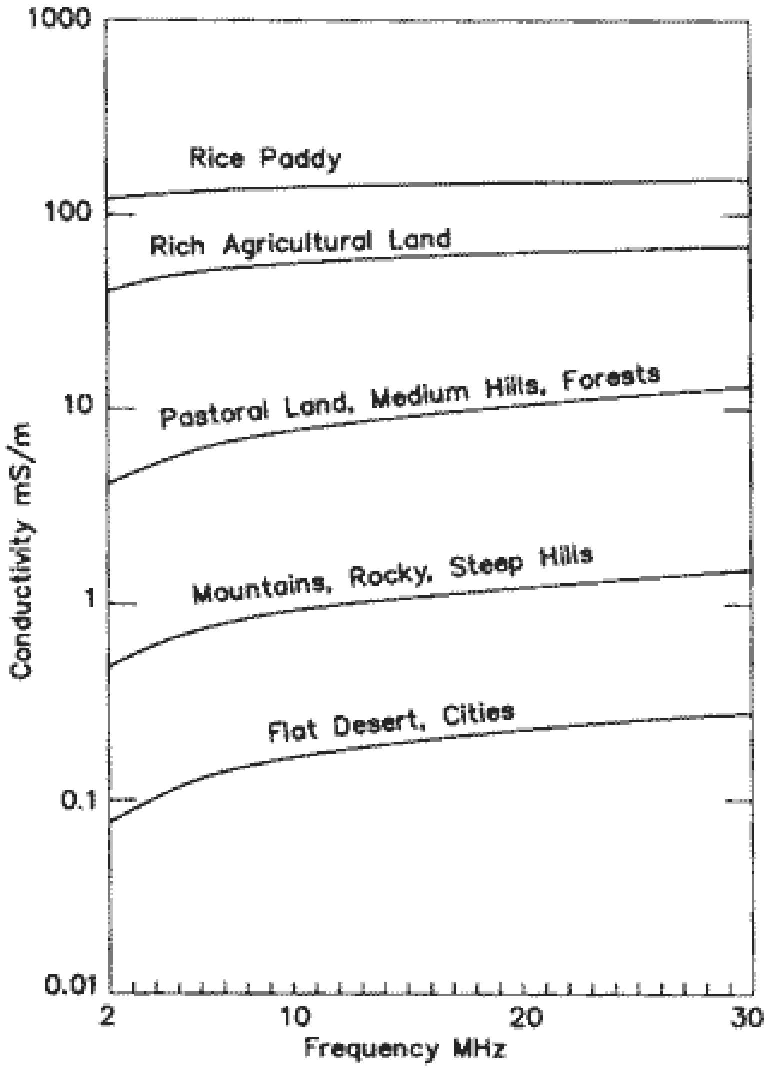
Conductivity Increases
Rising temperature produces ionization and the conductivity increases.

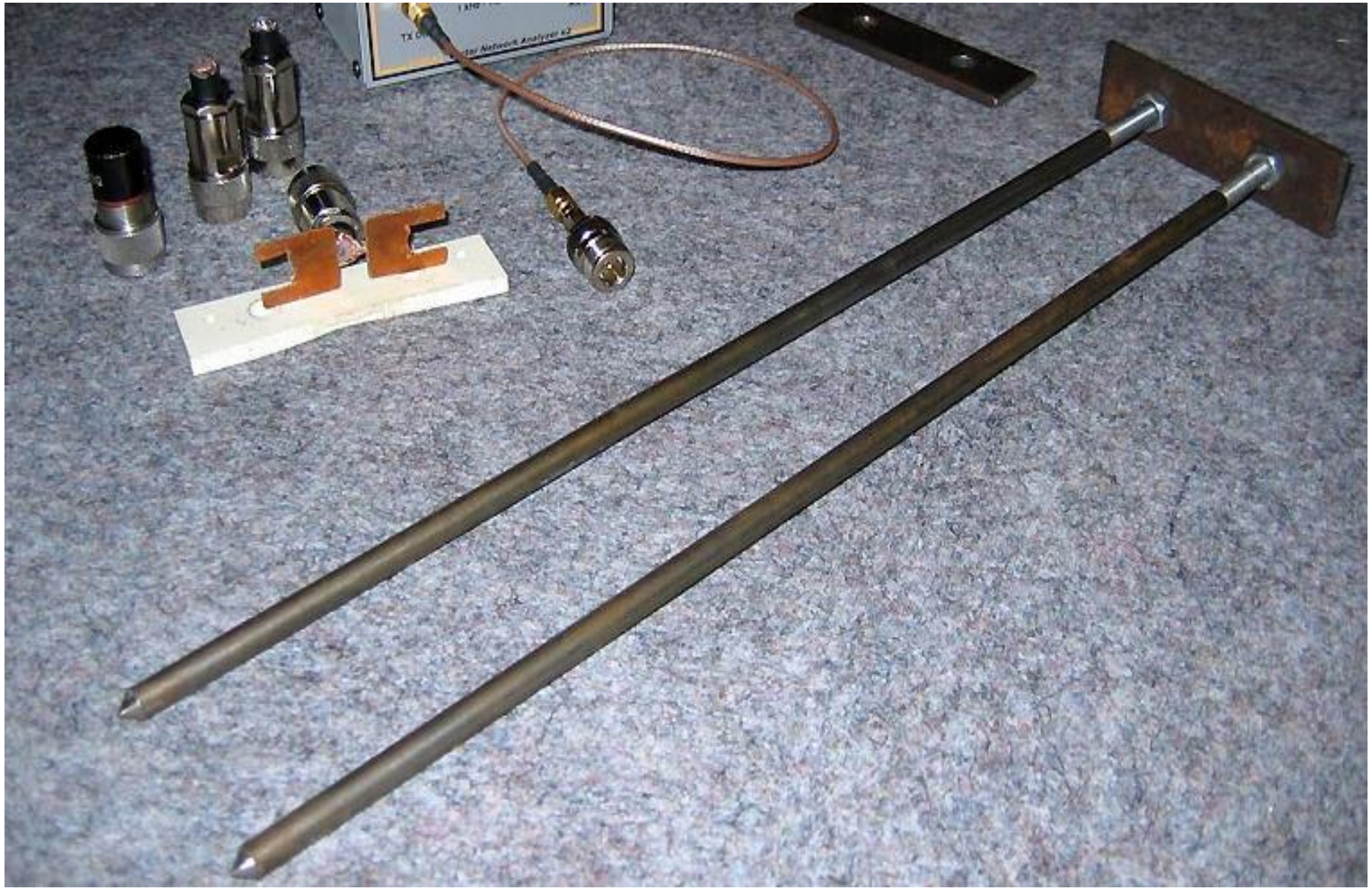
GROUND CONDUCTIVITY & EFFECT ON RADIO COMMUNICATION

1. **Ground conductivity** determines the field strength and propagation of surface wave (ground wave) radio transmissions.
2. Low frequency (30–300 kHz) and medium frequency (300–3000 kHz) radio transmissions are particularly reliant on good ground conductivity as their primary propagation is by surface wave.
3. **Ground conductivity** also affects the real-world radiation pattern of high frequency (3-30 MHz) antennas.
4. **ITU publishes an extensive world atlas** of ground conductivities.

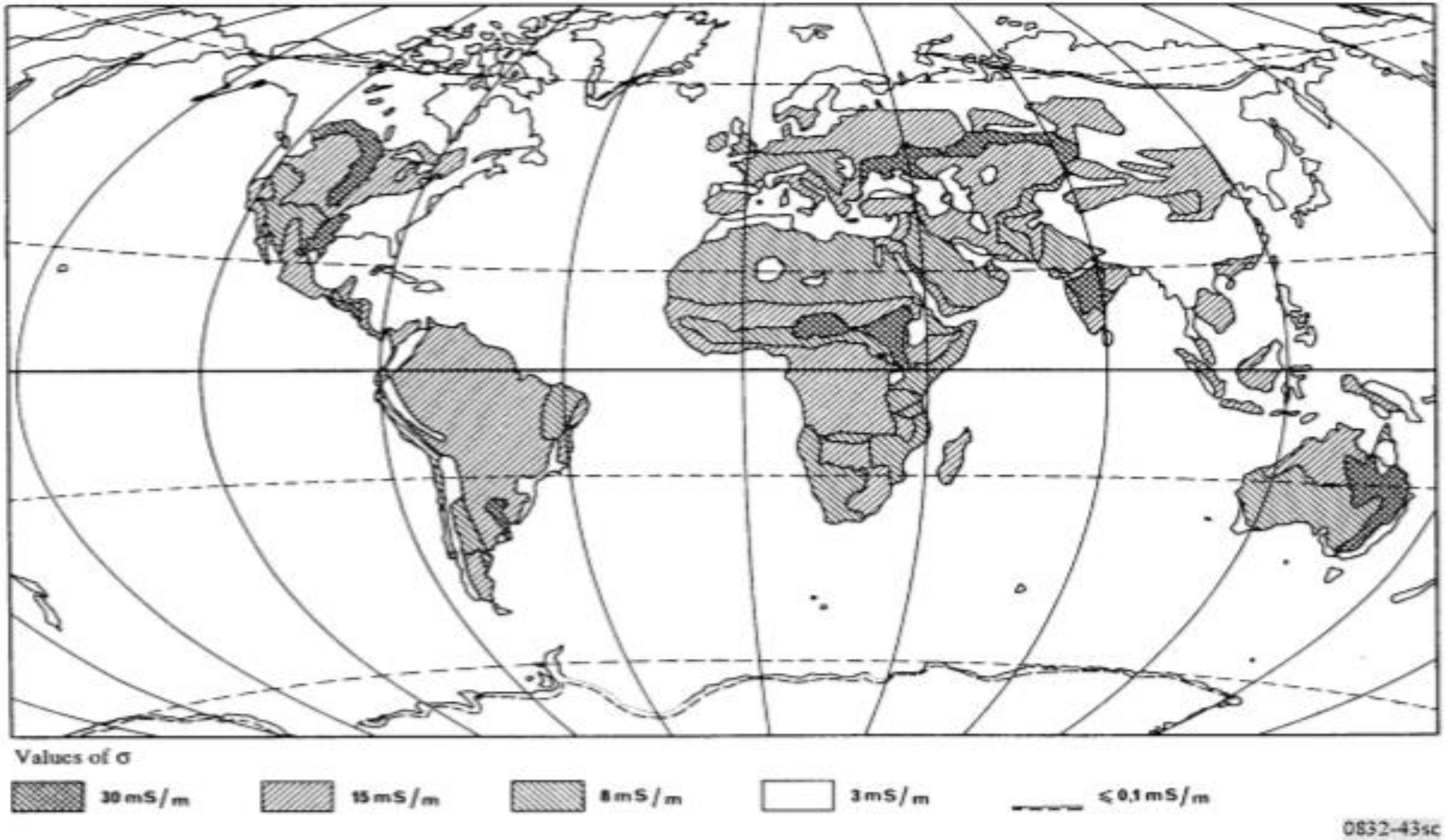


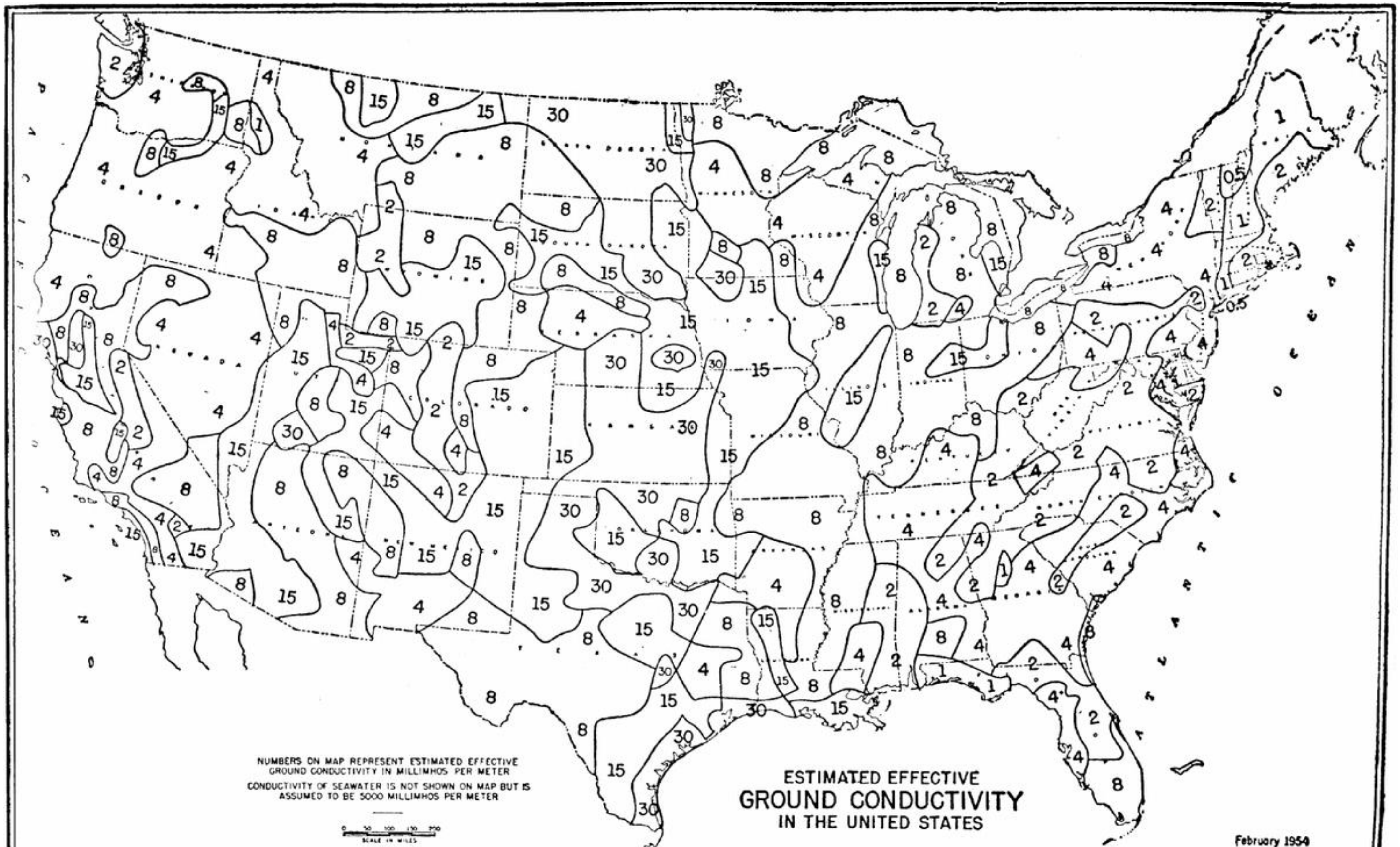
GROUND CONDUCTIVITY OF VARIOUS TERRAINS





ITU CONDUCTIVITY ATLAS FOR LAND AREAS

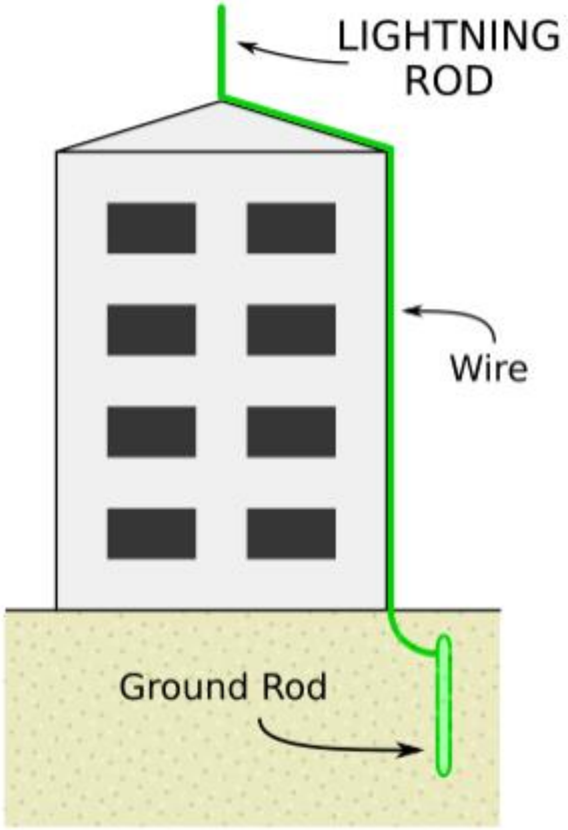




ESTIMATED EFFECTIVE
GROUND CONDUCTIVITY
IN THE UNITED STATES

GROUND CONDUCTIVITY & LIGHTNING PROTECTION

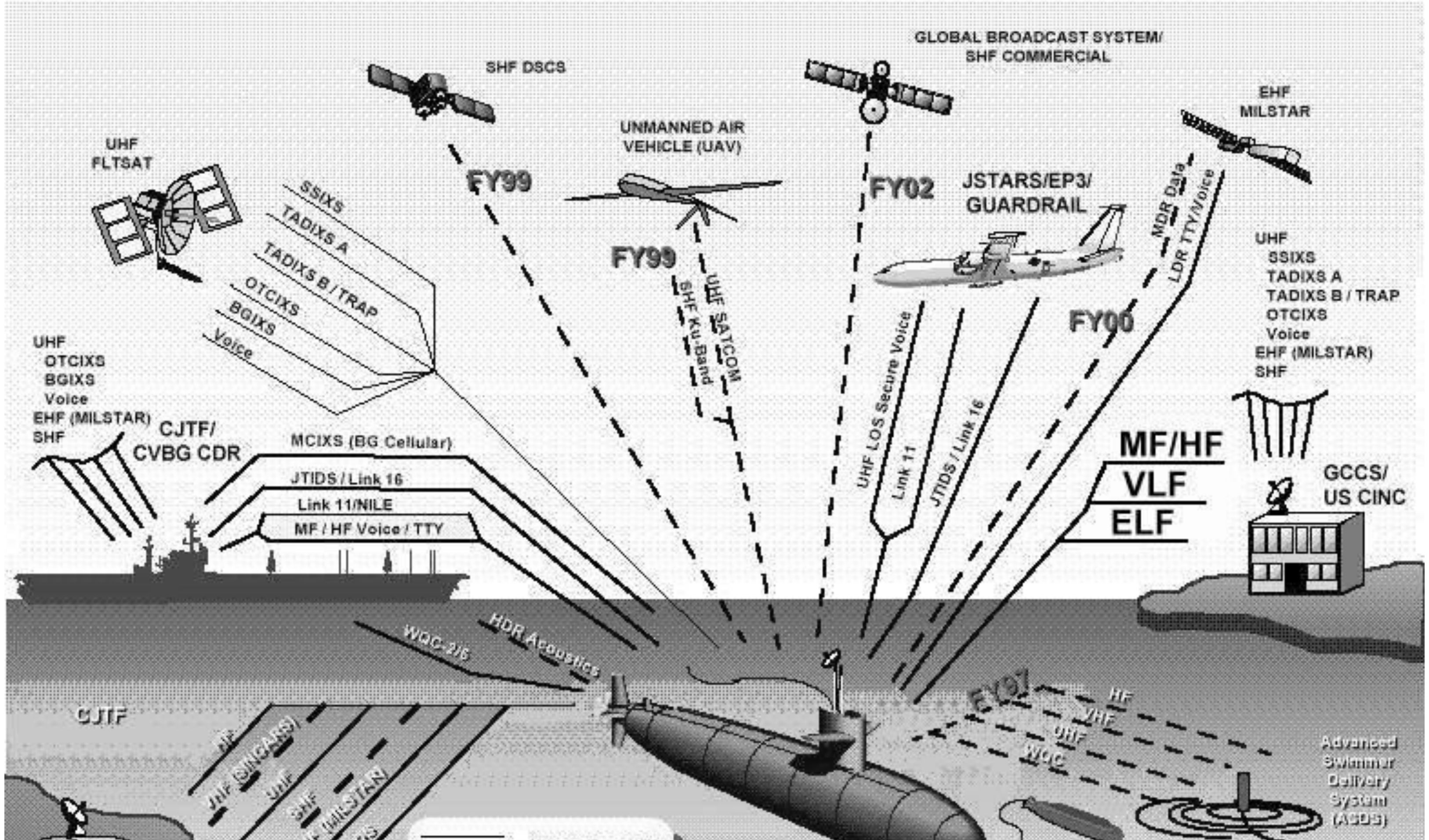
- **A lightning protection system** is designed to protect a structure from damage due to lightning strikes by intercepting such strikes and safely passing their extremely high currents to ground.
- The efficiency of the system depends on the electrical conductivity of the ground.



(a) Lightening protection system
We must first measure the conductivity of the ground to establish its ability to carry high currents

SUBMARINE COMMUNICATION

- Communication with submarines is difficult because radio waves do not travel well through good electrical conductors like salt water.

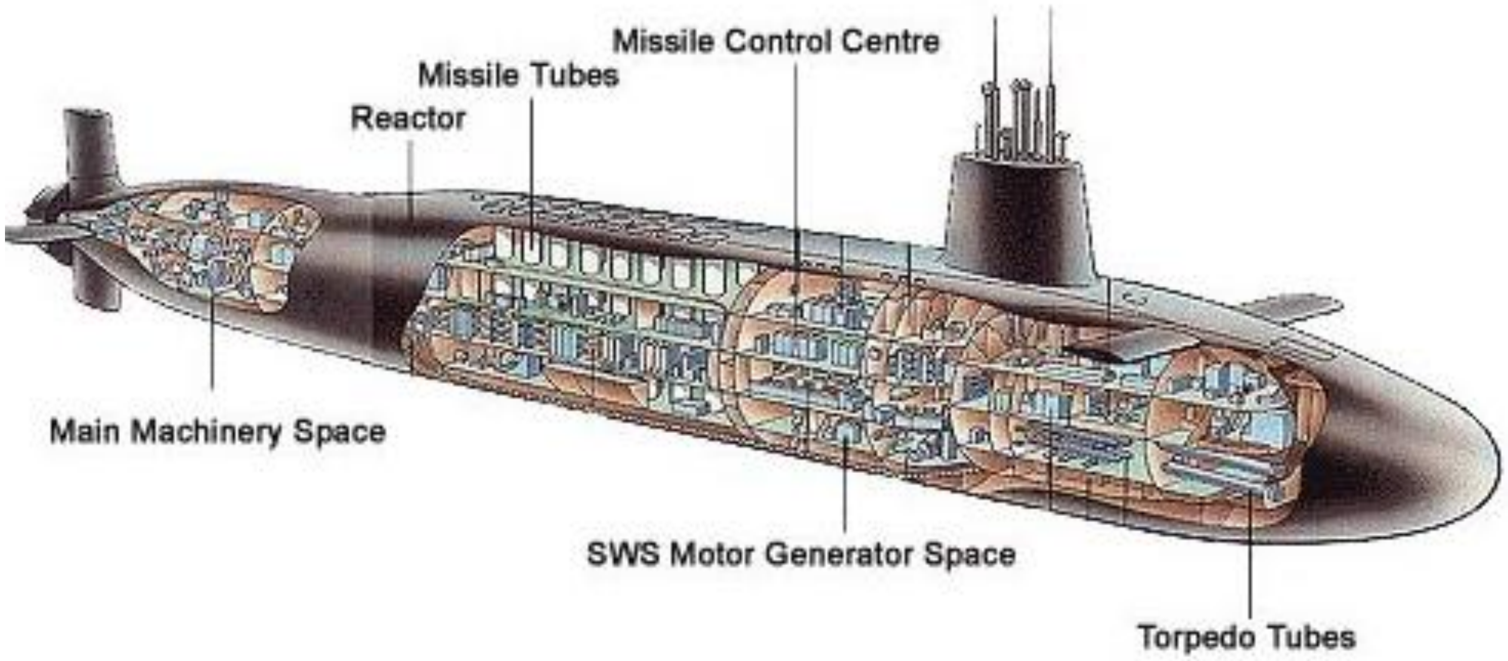


EVOLUTION OF SUBMARINES/1

- Early submarines mostly travelled on the surface, diving mainly to evade immediate threats because of their limited underwater speed and endurance.

EVOLUTION OF SUBMARINES/2

- During the Cold War, however, nuclear-powered submarines were developed that could stay submerged for months.



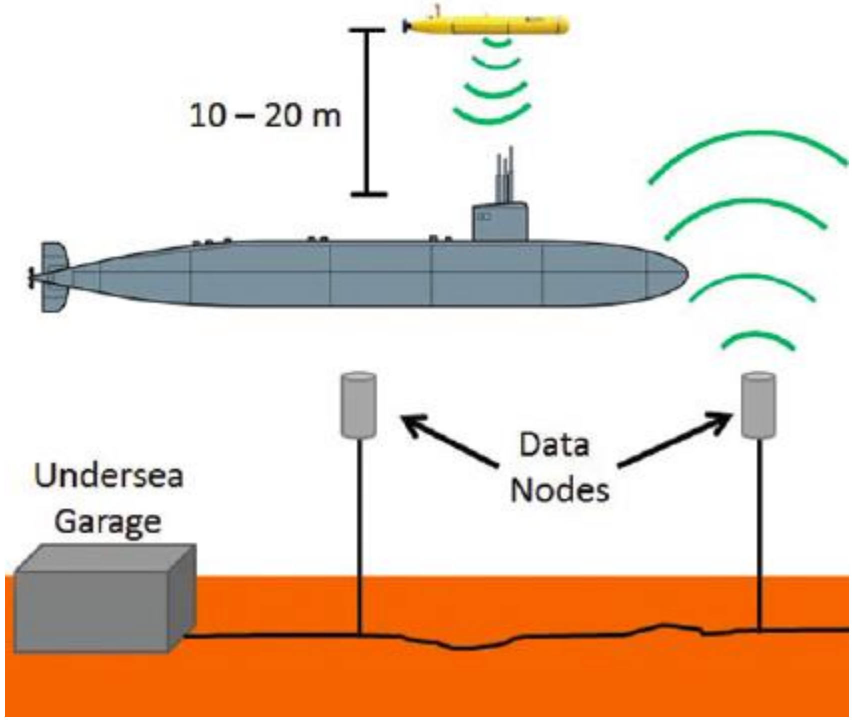
COMMUNICATING WITH SUBMARINES

- Submarine communication is restricted by the depth at which vessels can exchange information and the speed at which they can do so through the medium of water.

- To communicate with submerged submarines several techniques are used as follows:
  1. Acoustic transmission
  2. Using Very Low Frequency (VLF) band
  3. Using Extremely Low Frequency (ELF) band
  4. Using standard radio technology

1. ACCOUSTIC TRANSMISSION

- Sound travels far in water, and underwater loudspeakers and hydrophones can cover quite a gap.
- Modern Navies have placed sonic communication equipment in the seabed of areas frequently travelled by their submarines and connected them by underwater communications cables to their land stations.
- If a submarine hides near such a device, it can stay in contact with its headquarters.

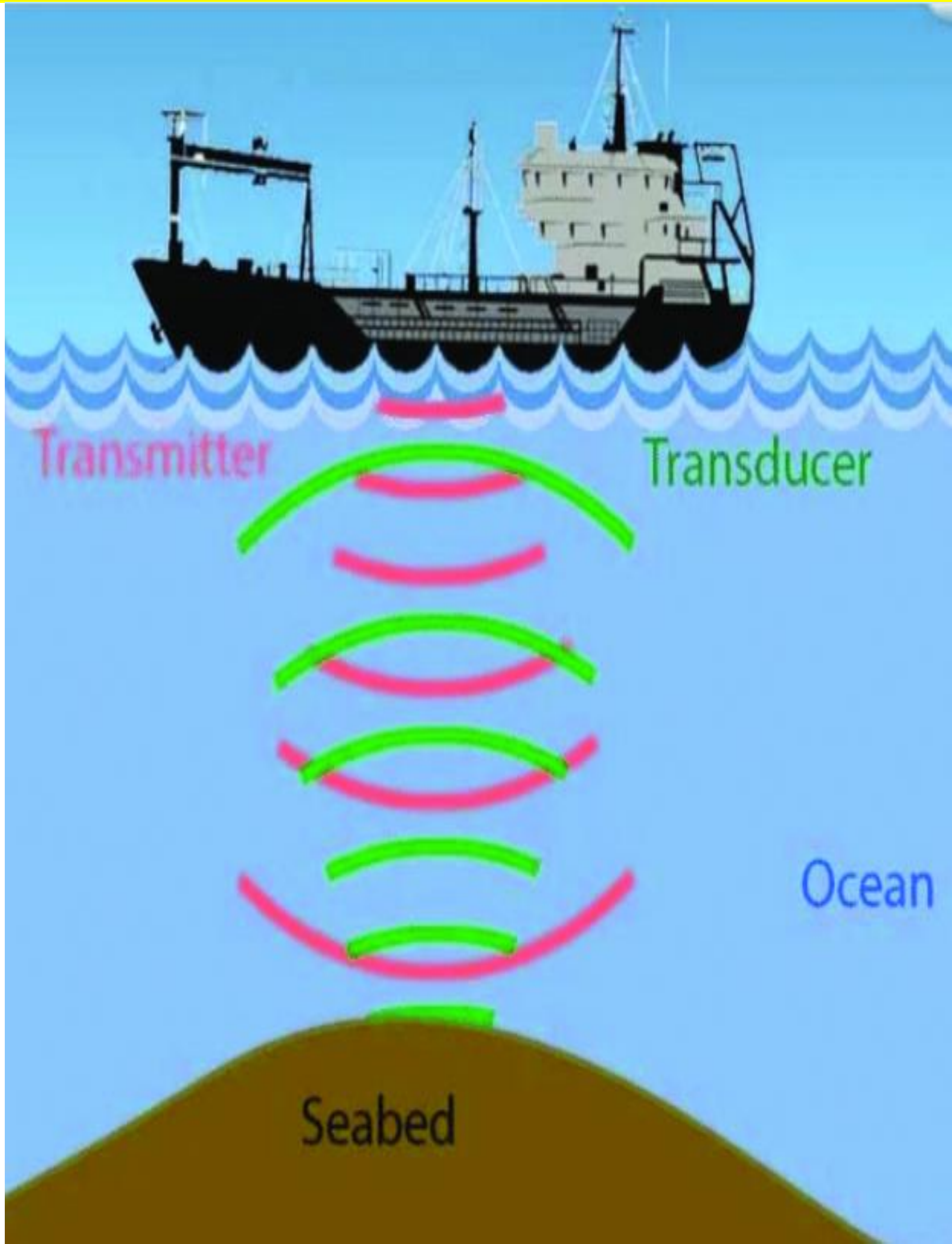


SONAR

1. **Sonar** (**SO**und **N**avigation **A**nd **R**anging) is a technique that uses sound propagation (usually underwater, as in submarine navigation) to navigate, communicate with or detect objects on or under the surface of the water, such as other vessels.

2. **Passive sonar** is essentially listening for the sound made by other vessels;

3. **Active sonar** emits pulses of sounds and listens for echoes.

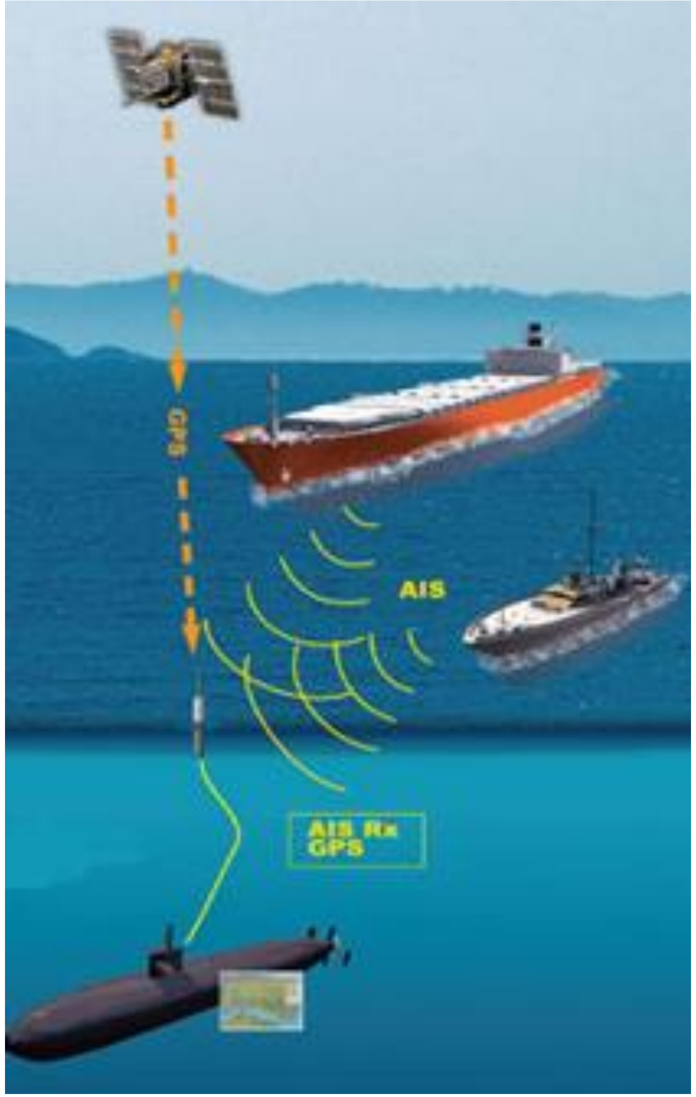


APPLICATIONS OF SONAR

- Military applications
  a) Underwater communication
  b) anti-submarine warfare,
  c) underwater torpedoes,
  d) Underwater security to detect amphibian vehicles and frogmen
- Civilian applications
  a) Fishing: Sonar used to find and harvest fish
  b) Echo sounding: Sonar used to establish the water depth below a ship or boat.

2. VERY LOW FREQUENCY (300 – 30,000 Hz)

- **VLF radio waves (3–30 kHz) can penetrate seawater to a depth of approximately 20 meters.** Hence a submarine at shallow depth can use these frequencies.
- A submarine more deeply submerged might use a buoy on a long cable equipped with an antenna.
- The buoy rises to a few meters below the surface, and may be small enough to remain undetected by enemy sonar/radar.



DISADVANTAGES OF USING VLF & ELF

Using VLF presents a number of disadvantages as follows:

1. The transmission antenna have to be very large, meaning the submarine must tow cumbersome antenna cables,
2. The submarine usually has to align on a specific orientation and reduce speed to obtain optimal reception.
3. The VLF and ELF frequencies only offer a very low bandwidth:
   a) VLF less than 1 Kb/s
   b) ELF sustains just a few bits each minute.
4. As a result, VLF and ELF cannot be used to transmit large datasets such as video.

3. USE OF STANDARD RADIO

- **Surfaced submarines** can use ordinary radio communications.
- Submarines may use naval frequencies in the HF, VHF and UHF ranges (i.e. bands), and transmit information via both voice and data modulation techniques.
- Where available, **dedicated military communications satellite systems** are preferred for long distance communications, as HF may betray the location of the submarine.