Sub-HF Search and Acquisition

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(U) This report summarizes the history of sub-HF search and discusses its present value to and future needs by SIGINT. The report concludes that a small automated effort at a few sites augmented by mobile search teams is adequate for the future.

1. OBJECTIVE

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2. INTRODUCTION

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Table 2.1.
Radio Frequency Bands Below 3000 kHz

DESIGNATOR	DESCRIPTION	FREQUENCY	WAVELENGTH
MF	Medium Frequency	300-3000 kHz	1000-100 m
LF	Low Frequency	30-300 kHz	1-10 km
VLF	Very Low Frequency	3-30 kHz	10-100 km
ULF	Ultra Low Frequency	300-3000 Hz	1000-100 km
ELF	Extremely Low Frequency	30-300 Hz	1-10 Mm
---	Pulsations	< 30 Hz	> 10 Mm

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(U) ELF, ULF, VLF, and LF waves propagate within the earth-ionosphere waveguide. Thus, their intensity is enhanced during ionospheric and magnetic storminess. (HF is degraded during such conditions because D-layer ionization causes more absorption). Absorption is very intense in the auroral and polar cap regions and also after the early hours of a high-altitude nuclear detonation.

(U) In seawater, radio wave absorption is 55 dB per seawater wavelength. VLF penetrates the ocean to depths suitable for receiving transmissions within tens of meters of the surface. To penetrate to greater depths, still lower frequencies are utilized.

(U) Pulsations are generated by natural events. Radiation from lightning discharges resonates in the earth-ionosphere waveguide at frequencies of about 7, 14, 21, etc., Hz. These frequencies may serve to monitor the sensitivity of receiving systems.

(U) Solar events (flares, chromospheric mass ejections) introduce shock waves and widespread turbulence in the solar wind which streams past the earth. This gustiness buffets the magnetosphere and generates emissions in the spectral range from pulsations to VLF. Below VLF energy is detected by loops, magnetometers, or Superconducting Quantum Interference Devices (SQUID).

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(U) LF and VLF are usually used for several purposes, e.g.,

(a) propagation into or within high latitudes to escape polar cap and auroral D-layer absorption,

(b) after high-altitude nuclear detonations (to avoid D-layer absorption),

(c) long-range ground wave coverage,

(d) long-haul communications, and

(e) communications to submarines (see section 3).

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(U) LF-VLF are also employed for through-the-ground communications, e.g., to missile silos or mine tunnels and for signalling along electric power lines for control of, and communications to, substations. The latter signals propagate along the power lines but also radiate and can be detected at some distance from the line. These frequencies are also

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used for tunnel-to-tunnel communications by the People's Republic of China (PRC) and other nations.

(U) Several maritime countries transmit at LF-VLF (U.K., U.S., France, India, etc.). North Korea and the PRC have an excess VLF capacity considering the size of their naval forces. Canada, Sweden, Norway, and the USSR have used VLF for communications northwards into the auroral and polar regions.

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(S-CCO) [redacted]

3. RADIO WAVE PROPAGATION

(U) This section briefly augments material presented in Section 2.

(U) Radio-wave propagation above about 500 kHz follows the usual ionospheric pattern: single or multiple reflections between the E (100 km) or F (300 km) layers and the ground. This topic is discussed in a variety of standard texts and will not be pursued here. Suffice it to say that radio waves above about 500 kHz first penetrate the D layer (about 80 km) before being refracted by the higher layer. The D layer can be highly absorptive for HF with absorption varying inversely as the square of the frequency. The absorption increases during daylight and particularly with increasing solar and magnetic activity. The latter condition usually occurs after a specific solar event. VLF and lower frequencies propagate below the D region so that their intensity, rather than decreasing, increases during periods of marked solar or magnetic activity.

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(U) At VLF and below, energy may be detected along three axes, vertical (Z), east (X), and north (Y). The vertical component attenuates rapidly with distance. Thus, if at a given receiving site all three components are detected, the source must be local. Distant energy will be received only as horizontal components. ELF attenuates at an average rate of about 1.5dB/Mm. Thus, one to two transmitters can cover most of the globe.

(U) Note that waveguide or ducted propagation exists with a variety of different conditions: (a) VLF and below, between the earth and the D layer, (b) VLF in the magnetic field aligned ionization duct to the opposite hemisphere, (c) UHF (300-3000 MHz) and higher frequencies in the non-ionized temperature-water vapor ducts of the troposphere, (d) light in fiber optic cables, and (e) compressional wave propagation in the temperature-salinity ducts of the oceans. In all cases the mathematics is similar to the propagation efficiency depending on the ratio of wavelength to duct size and the properties of the waveguide.

(U) Every wave guide has specific cutoff frequencies. In the sub-HF waveguide, the cutoff ranges between 4 kHz and 8 kHz; within this range only local emissions, e.g., as from lightning strokes, are observed. This cutoff varies with time.

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(U) Strong natural emissions may be generated by the interaction of the solar wind and the magnetosphere. These emissions may extend to 5 kHz or more and on occasion may be so intense that they obscure all signals. Solar sub-HF emissions maybe detected above the ionosphere.

4. HISTORICAL BACKGROUND

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5. STATION EQUIPMENT AND OPERATION

5.1. Stations

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5.2. Equipment

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5.3. *Administrative Prosecution*

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5.4. *Summary*

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6. SEARCH RESULTS DURING PAST YEARS

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Table 6.1.

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7. THE FUTURE THREAT

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Table 6.2.

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8. CONCLUSIONS AND RECOMMENDATIONS

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