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The Future of High Frequencies in Cryptology

Part I

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Editor's Note: Part II will follow in the next issue of *Cryptologic Quarterly*.

~~(S)~~ *Cryptology is now beset by many difficult problems at a time of curtailed funds and rapid technological innovations in communications (e.g., digital signaling, multiplexed transmissions of voice, data and documents, proliferation of compressed speech, increased COMSEC awareness, and global availability of cheap, sophisticated equipment). It is imperative to reexamine traditional operations and introduce concepts designed to meet challenges of the future in SIGINT's three main areas: intercept, analysis, and timely distribution of significant end product reports. This paper attempts to address only one portion of the first item: high frequencies (HF, 3–30 MHz). For SIGINT, HF is intensive in manpower and costly in maintenance. In other portions of the spectrum, operating funds may be smaller, but the initial capital investment is very high. The proportion of funds allocated to different spectral regions should consider the intelligence value of each region. This paper shows that HF still remains one of the most important contributors to SIGINT.*

~~(S-CCO)~~ *High Frequency has been and will be an invaluable asset to SIGINT. It has provided intelligence of extreme value to the nation. Despite a shift of traffic to other circuits* [redacted] *HF will remain as an effective, indestructible means of communications well into the future. The question facing SIGINT in an era of shrinking dollars and expanding requirements is that of introducing greater efficiencies into HF – in collection, analysis, and processing. The present system is too inflexible, both technically and geographically. It was not designed to confront merging communications techniques or geographically fragmented political targets. SIGINT for HF must make choices, some of which include greater use of ships, adaptive antenna arrays, and transportable advanced automated remoted sensors.*

~~(S)~~ *The objective of this paper is to stimulate discussion on the future architecture of HF in relation to SIGINT. First an outline of the past value of HF will be presented and then an indication of the future SIGINT needs for HF. Critical evaluation is essential in order to optimize decisions on the allocation of cryptologic resources.*

HISTORICAL

~~(U)~~ HF has been employed for long-distance communications since its discovery by radio amateurs in the 1920s. Marconi's previous transmissions over long distances had been accomplished using Very Low Frequency (VLF, 3–30 kHz) or Low Frequency (LF,

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30–300 kHz), which required high towers and high powers. At that time HF was unexplored by and was assigned to the radio amateurs until they demonstrated its usefulness.

UTILITY

~~(S)~~ HF provides a simple, effective means for long-distance communications. It can be used by relatively untrained individuals (e.g., amateurs, terrorists, drug traffickers, and illegals). All equipments that use low power are readily available off the shelf at low cost. Present equipment, which can include encryption and spread spectrum, will become much more complex in the future. The trend in transmitter design is towards low-power burst-type emissions (fractions of a second). Should they materialize, these systems may cause a resurgence for HF communications but may cause great difficulties for the interceptor. The great limitation of HF systems is the variability arising from the dynamic ionosphere. Even with this deficiency, HF is effective, and it can be the primary means of communications for the Third World and illegals. It will always remain within any integrated communications systems of the great powers. Many examples can be cited (see Gerson, 1991), but only a few will be noted here.

SIGINT AND HF

~~(S-CCO)~~ SIGINT enlarges the definition of HF to 1–40 MHz and interacts with it in three areas: search, intercept, and target location via HF Direction Finding (HFDF). [redacted] (see Gerson, 1991). However, since the 1950s changes have occurred, i.e., proliferation of other communications systems of greater reliability and larger bandwidth. This change shifted some traffic to Very High Frequencies (VHF, 30–300 MHz), Ultra High Frequencies (UHF, 300–3000 MHz), and now optical systems.

~~(S-CCO)~~ Despite the availability of new systems, HF communications persist and will never disappear. Crucial questions for SIGINT are these: "How much effort and resources should be devoted to HF in comparison with those for other frequency purposes?" "What is the proper mix of resources?" This paper attempts to provide an overall review of HF. However, it is imperative to consider the new threats (economic, military, fiscal, and political), the frequencies being used, and the potential intelligence to be derived. HF will be found to be at least as important in the near future as it has been in the past.

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SIGINT VALUE

General

~~(S-CCO)~~ It cannot be overemphasized too strongly that SIGINT must include HF (see Gerson, 1991). If anything, a greater proportional emphasis may be initially required. As one example, consider first the military threat. Prior to 1991 the Soviet Union was the only nation that could destroy the United States. [redacted] (Gerson, 1991). The disintegration of the Soviet Union means that the communications and military capabilities of the new entities will not disappear but will be inherited by them [redacted]

~~(S-CCO)~~ Third, consider the Third World and those outside the law: terrorists and smugglers (drugs, arms, currency). For them HF use is increasing. They can use the new modulations, new services, and emerging developments becoming available in HF. It must be assumed that any dramatic movement from HF remains years away. Obviously, the sophisticated HF services will disperse throughout the world. As the sophistication of this technology increases, more complex systems will be introduced into HF and will be employed by civil and commercial entities in the emerging nations. [redacted]

~~(S-CCO)~~ Further, as a trend in communications [redacted] was moving towards connectivity wherein a frequency continuum is used. Rapid switching allows messages to move over open lines; HF plays a vital role in this process. In short, SIGINT must monitor HF as well as, or even more than, other frequency bands.

~~(S-CCO)~~ Finally, even the United States itself has not abandoned HF. [redacted]

Search

~~(S)~~ National Security Council Intelligence Directive No. 6 assigns the mission of spectrum surveillance to NSA (all frequency bands: RF, IR, VIS, etc.). The value of HF search was demonstrated repeatedly during World War II. Although resources have since declined, HF research still remains invaluable.

~~(S-CCO)~~ To fulfill its mission, the search operation must become much more efficient with greater use of transportable Remote Operations (ROF) or Collection Facilities automation and better-trained personnel.

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HF Intercept

~~(S-CCO)~~ Even up to DESERT SHIELD/STORM, HF provided more valuable intelligence than any other frequency band. This condition arose because HF was extensively used for many communications.

~~(S-CCO)~~ During the cold war most targets were Communist, necessarily fostering the establishment of many large HF intercept sites in the Northern Hemisphere, [redacted] SIGINT prudently concentrated on Soviet, Chinese, and associated targets whose formats and operations then became fairly well known. The attention given to other nations was modest in comparison.

~~(S-CCO)~~ In practice, HF intercept and direction finding were combined at specific locations having large Circularly Disposed Antenna Arrays (CDAA). Mobile platforms (aircraft) were employed to complement the fixed sites.

~~(S-CCO)~~ A series of painful experiences (Vietnam, Iran, Central America, Iraq, etc.), shattered the illusion of one tidy world, one concentrated threat, primarily military. Today additional concerns regarding economics, commerce, finance, narcotics, and politics bring new SIGINT targets, located in different and distinct geographic areas. (Most existing HF sites were not located for the new geographical threats nor equipped for the new HF technologies. [redacted]

Target Location

~~(S-CCO)~~ HFDF is still considered one of the best means for locating targets on the oceans. [redacted] This capability is obtained through the manpower-intensive operation of many large fixed sites. HFDF is also used to locate land targets and, to some extent, to steer intercept operators to their correct HF transmitter.

[redacted] The topic of HFDF has been the subject of many studies over the years, but its concept, design, and operation have not changed significantly.

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~~(S-CCO)~~ Many costly attempts were made to prove the accuracy of measured HFDF Lines of Bearing (LOB) and accuracies of the resulting fix, all without material success. Fix accuracies (about 100 km radius) are still considered unsatisfactory but acceptable. The inaccuracies stem from two factors: geometric dilution (a function of distance and crossing angle of the LOBs) and the unpredictable variability of tilts in the ionosphere that deflects HF rays out of the great circle plane. It is doubtful if the latter effects can be eliminated. A number of Single Site Location (SSL) systems exist. Again the changeable ionosphere limits location accuracies (commonly but erroneously assumed to be only about 10 percent of range).

~~(S-CCO)~~ Several general comments should be made about geolocation accuracies. An accuracy within 100 km may be adequate for locating a ship somewhere on the high seas, but it may be completely unacceptable for tactical purposes. Accuracy requirements vary widely and depend upon the intended use. To "lay metal on a target" requires accuracies within meters. For HF rays returned from the ionosphere, such accuracies are unattainable. Obviously, LOBs in the wrong transmitter are worthless.

~~(S-CCO)~~ Inherent limitations of the existing HFDF network must be noted. It is aging, immobile, and manpower intensive. Using HF skywave, targets cannot be located within the skip distance or when "up and down" communications are used. It is geographically inflexible, physically unwieldy, and becoming technically deficient. In addition, it has fulfilled its designated purpose for the political and military threats of the period. However, the time has come to reassess the SIGINT need of the entire system including cost, location, and innovation. Since SIGINT must maintain a capability for tactical and strategic target location and intercept, new sites, advanced equipment, new concepts, and different, smaller sites (ROFs) must be introduced.

~~*Summary*~~

~~(S-CCO)~~ During and after World War II, HF was an outstanding contributor to SIGINT in search, intercept, and target location. However, while the world changed, the system did not. It remained essentially stagnant both geographically and technically. In the meantime, HF technologies advanced and political threats dispersed. For SIGINT, HF cannot disappear. It will always be useful and needed. Further, the global capital investment in HF is too large to be disbanded. With funds and resources declining, the SIGINT HF mission must become more efficient, automated, and flexible in order to maintain the orderly

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prosecution of collection, search, and signal processing. [redacted]

~~(S-CCO)~~ In short, HF is a viable contributor to SIGINT. To meet impending technical and political challenges (strategic and tactical), operations must become more flexible (geographically and technically). Considering the importance of HF to SIGINT, the percentage of cryptologic funds devoted to it may initially increase not decrease. Smaller, more mobile, automated and advanced facilities, transportable when necessary, must be implemented. Financing for the capital costs must be considered.

ADDITIONAL HF CONSIDERATIONS

Ionospheric Predictions

~~(S-CCO)~~ Some comments should be made about ionospheric predictions, which are employed in planning and, to some extent, in operating HF systems (e.g., communications, radar, or intercept). Predictions are based upon two main considerations: (a) ionospheric climatology (dependent upon location, time of day, year, and solar cycle) and (b) engineering factors (transmitter power, soil, antenna types, local noise environment, etc.). There are numerous prediction codes; all cumbersome, all inefficient, and many internally inconsistent. Nonetheless, for practical purposes, all provide about the same results.

(U) The DoD and NSA have applied considerable effort in attempts to improve the predictions, all with marginal, if any, success. A good portion of the problem lies in the fact that the ionosphere is a fluid whose physics and dynamics are not fully known. This fluid is controlled by the sun, whose changes still remain unpredictable. Until the forces influencing the state and movement of the ionosphere can be better defined, material improvements of the predictions will not be possible, irrespective of the funds applied.

(U) However, some studies of the ionosphere are warranted and necessary. The Arctic, in an age of fuel awareness, is destined to become a transportation and communications highway from North America over Siberia to Europe, Asia, and China. At present it also contains a military threat, where armed submarines roam the ocean depths and aircraft ply the polar skies. For communications, additional knowledge of the arctic ionosphere is needed. In an era of declining funds, efforts must be shared. Canada, which "owns the aurora," already has institutions (University of Alberta, University of Western Ontario, Communications Research Center, etc.) preeminent in studies of the polar and auroral ionospheres. Canada should be encouraged to assume full responsibility for investigating this region. Similarly, Australia should be encouraged to assume responsibility for examining the equatorial ionosphere.

(U) Further, within the United States, the DoD should amalgamate the disparate, overlapping, and sometimes wasteful efforts on "improving ionospheric predictions." The entire responsibility should be assigned to one triservice group, e.g., within the Air Weather Service (AWS), charged with generating, improving, and maintaining any and all prediction codes needed by the DoD (and NSA). DoD elements, connected via some

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networking scheme, requiring predictions would transmit queries to AWS and obtain instant responses. Past uncooperative, individualistic efforts have squandered resources and have distributed incompatible, deficient, prediction codes throughout the DoD. The waste must stop.

Ionospheric Disruptions

~~(S-CCO)~~ A high-altitude nuclear detonation would disrupt the ionosphere for about an hour or less. The United States conducted tests in the Pacific to examine this effect during the 1950s. The Soviet Union, taking advantage of these "tests of opportunity," concluded that the ionosphere is self-healing under sunlight and returns to normal in about thirty to fifty minutes after the detonation. [redacted] The United States arrived at the opposite conclusion, that HF would be unusable. On the basis of SIGINT, however, U.S. views were later reversed. In summary, after a high-altitude nuclear detonation the ionosphere may be disrupted for a short period but not destroyed.

Technical Challenges

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Fiscal Trends

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CONCLUSIONS

a. ~~(S-CCO)~~ From the past to the present, HF has been an outstanding contributor to SIGINT primarily because most communications of intelligence interest depended upon this means. This condition will prevail in the immediate future.

b. ~~(S-CCO)~~ Also in the past, most attention was prudently given to one generalized military threat, Communism, embodied by the Soviet Union, China, and their associates. The past, convenient, easily identified SIGINT focus has been shattered by several factors: emergence of new threats (military, economic, fiscal, narcotic, commercial) sprinkled around the globe, some dilution (not elimination) of the Communist threat, and the creeping introduction of sophisticated HF communications technology (not readily handled by existing SIGINT sites).

c. ~~(S-CCO)~~ HF search is a vital ongoing requirement. While it must be maintained, it must become more efficient, i.e., [redacted]

d. ~~(S-CCO)~~ Better-trained and more efficiently used manpower is essential for SIGINT sites. Manning by poorly trained individuals degrades search copy and other functions. Consideration must be given to (1) recruiting only individuals who first served a term as communicators and thus are trained in many skills required for SIGINT or (2) using

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[redacted]

f. ~~(S-CCO)~~ a triad of shipborne ROFs whose positions are known through the Global Positioning System (GPS) could serve a crude local HFDF net concentrating on the crisis area of interest.

[redacted]

h. ~~(S-CCO)~~ Unless they are remoted, continued operation of the existing HFDF [redacted] network is illusionary. It is technically inflexible and manpower intensive. It cannot handle geographically dispersed emergencies and advanced emerging technologies. Replacements of the same aperture are unlikely. [redacted]

i. ~~(S-CCO)~~ For SIGINT, wideband communications trunks are essential to interlink sites and allow timely interchange of information.

j. ~~(S-CCO)~~ SIGINT sites should conduct periodic checks on internal system performance, e.g., antennas, noise, receivers.

k. (U) Ionospheric prediction services should be assigned to the Air Weather Service. Investigations in specific geographical areas (the Arctic, equatorial regions) could be assigned to Canada and Australia, respectively. Costs must be shared.

[redacted]

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~~(FOUO)~~ Mr. Gerson, a physicist, has been with R6 since April 1988. Previously he had been with R5. He was one of the founders of the Air Force Cambridge Research Laboratories (now AFGL) and chief of its Ionospheric Physics Laboratory (1948–56). He was secretary of the U.S. Committee for the International Geophysical Year (IGY) (1953–57), secretary of its Executive Committee, vice-chairman of its Arctic Committee, chairman of its first two Antarctic committees, and a member of its Ionospheric and Rocketry panels. Mr. Gerson has served as consultant to ARPA; Lincoln Laboratory; Mitre Corporation; and Syracuse University Research Corporation. He has had over sixty scientific papers published in American and foreign journals.

While serving on the U.S. National Committee for the IGY, he suggested transarctic submarine transit, wrote the report for the U.S. Antarctic Expedition, and selected the U.S. South Pole site. Mr. Gerson is the only Agency employee to have been sent to both the Arctic and Antarctic; his total TDY time in polar regions exceeds 48 months. A survey of his early accomplishments appeared in *Physics in Canada*, January 1984.

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