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Sigint Technical Primer—III

On the Radio Spectrum and Communications Modes

This article, the third in a series on communications techniques published in the Sigint Technical Primer series, briefly discusses such subjects as the radio frequency spectrum and communications modes. Previous articles in this series by Mr. Jacob Gurin discussed modulation, antennas, and, to a lesser extent, multiplexing. They were published in the Fall 1971 and Summer 1972 issues of the *Cryptologic Spectrum*.

As Mr. Gurin pointed out in his article on modulation, it is certainly possible for persons (including many in the NSA/CSS) to get through life without knowing the difference between AM and FM modulation, or even their meanings. And this is also true of many of the other communications and electronics techniques. But in the business that the NSA/CSS is concerned with—exploiting foreign signals—it is to the advantage of persons involved to have at least a basic understanding of the techniques which target nations employ to communicate, or will employ in the future.

Why? Because it will enable employees in the various disciplines to better recognize, evaluate, and report these techniques, thereby yielding a more comprehensive and reliable communications and electronics picture of the target. At the same time, it will enable these persons to do a better job in recognizing and reporting advances in the various techniques as they occur, and how these advances will influence communications security and efficiency of the targets, what they mean in relation to other Sigint or collateral on the subject, what they mean in so far as their significance to the overall effort of the target nation is concerned, how various communications subsystems tie in to form a major system, the purpose, or estimated purpose, of each subsystem, and the like.

In short, communications and electronics capabilities of a country contribute to its total military and economic capability, and consequently such matters are targets for intelligence exploitation. And with future trends in these areas presenting a picture of pyramiding difficulties for the Sigint effort, decision makers and planners require the fullest possible information on the present status and future development of target communications and electronics techniques and facilities. And they need it with as much lead time as possible.

With this in mind, perhaps the best place to begin is with the radio spectrum itself; that is—what is it, what are its limits, what kinds of signals and services could be expected in certain of its segments (and why), what is its associated terminology, etc.?

The Radio-Frequency Spectrum

In the 70 or so years since Guglielmo Marconi first demonstrated his trans-Atlantic wireless telegraph, the useful radio spectrum has been steadily expanded to include ever higher frequencies and has been divided and subdivided many times to provide space for dozens of new applications as they appeared. Today the radio-frequency spectrum is, for the most part, precisely allocated by international agreements among a wide variety of competing communications services. It ranges up to 300 GHz,[1] although the "officially allocated" part extends

[1] One Hertz (Hz) = one cycle.
One Kilohertz (KHz) = one thousand Hz.
One Megahertz (MHz) = one million Hz.
One Gigahertz (GHz) = one billion Hz.
One Terahertz (THz) = one trillion Hz.

from 10 KHz to 40 GHz. This segment of the spectrum is populated by communication services of various kinds, with the lower part—below about 500 MHz—by far the most densely populated. And although the various services are precisely allocated to segments, there are exceptions to actual usage by countries of the world. Some countries, for example, do not adhere to international agreement and establish their own divisions. Still others assign their military, and certain other communications, anywhere they please, mainly to enhance security of these communications by making their detection and interception more difficult. The segment above 40 GHz is officially reserved for experimental usage, and it seems likely that communications technology will skip much of this part, and instead jump directly to optical wavelengths.

Over the years certain regions of the radio spectrum have acquired distinctive labels. For example, the region between 3 and 30 KHz is designated very low frequency (VLF), the region between 3 and 30 MHz high frequency (HF), the region between 30 and 300 MHz very high frequency (VHF), and so on. The VHF is used for such services as FM and television broadcasting and for aviation and other mobile communications. The UHF or ultra high frequency (300 to 3000 MHz) provides even more television channels than the VHF region and is used for such services as aeronautical and other mobile communications, microwave relays, meteorological satellites and radio-location systems. Radio links operating in the super high frequency (SHF) and the EHF or extremely high frequency regions (from 3 to 30 and 30 to 300 GHz respectively) make available large bandwidths for carrying thousands of voice channels.

In the lower bands, where spectrum "space" is in such short supply, a number of techniques—such as single sideband and independent sideband—are used to conserve as much of this limited area as possible. Use of these spectrum-saving techniques cut the bandwidth requirements of an AM voice signal markedly, while affording the additional bonus of sharply reducing the amount of power needed to send the signal the desired distance. In these lower bands (below about 400 MHz) will also be found heavy concentrations of such signal modes, modulations, and keying techniques as Morse, printer, AM double sideband, FM single channel voice, frequency shift keying, double frequency shift keying, phase shift keying, and multitones. Most of these techniques are also employed in the higher regions of the spectrum, but in these higher bands they are usually contained within wideband multichannel signals. Military tactical communications (both single channel and multichannel, both FM and AM modulated) appear in almost any part of the spectrum, but the HF, VHF, and low-UHF (below about 500 MHz) are the most heavily used for these purposes.

The capacity of a channel is commonly expressed by the bandwidth. Thus, a "standard" voice signal is assigned a bandwidth of four KHz, whereas a U.S. television signal is assigned a bandwidth 1500 times greater (six MHz). And because higher frequencies require line-of-sight pathways and because the earth is round, relay towers have to be installed every 20 or 30 miles, depending on the terrain. Conversely, at the lower end of the radio-frequency spectrum bandwidths of signals are of necessity much narrower, because, as noted previously, there is not the "room" available in this part of the spectrum that there is at higher frequencies. But signals at the lower frequencies can be propagated much longer distances than those in the upper end of the spectrum without the necessity of these expensive relay towers.

Ground terminals such as this can send and receive multiple channels of information to and from orbiting communications satellites.

Another item of interest is that frequency ranges in the various bands of the radio spectrum are not equal—rather, the range of each higher frequency band increases by a factor of 10. For example, the range of the LF band is 270 KHz, the MF band 2700 KHz, the HF band 27,000 KHz, and so on. Thus, there is much more space in the EHF band than in the LF band (270,000 MHz compared to 270 KHz). This is one consideration in the trend toward the use of higher and higher frequencies to meet the demand for the additional room required by the ever increasing number of signals on the air. Another significant consideration, as mentioned previously, is that in the higher bands there is much more space for the relatively wider bandwidths of such signals as television, video-data, and multichannel radio-relay.

It should also be noted that the radio-frequency spectrum, despite its wide range, is but a small part of the entire electromagnetic spectrum. The radio-frequency portion is in fact at the lower end of the electromagnetic spectrum with regard to frequency. Above the maximum frequency of the EHF band are infrared rays, visible light, ultraviolet rays, X-rays, and gamma rays.

Electrical Modes of Communications

Essentially, the electrical modes of communication consist of devices and systems which convert information to be transmitted into an electrical form, which they subsequently convert back to a form suitable for human comprehension. The electrical form may be transmitted directly over wire lines, or it may be used to modulate radio-carrier waves.

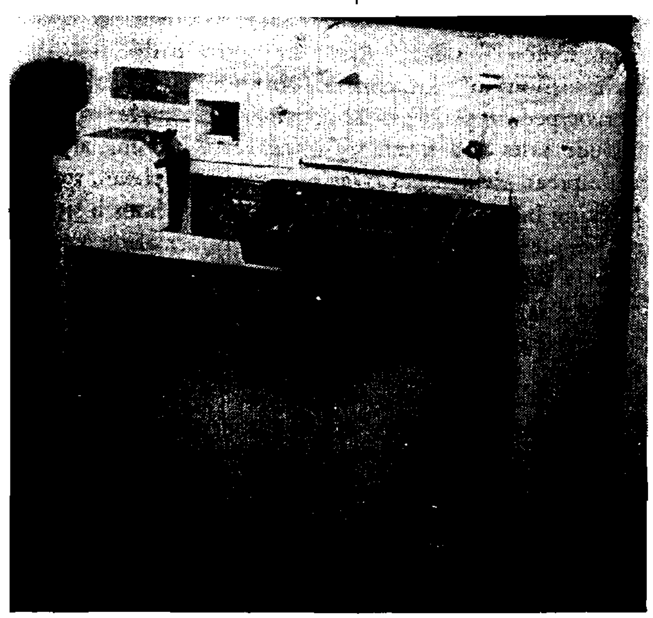
The electrical modes of communications include such varieties as Morse, teleprinter, telephone, and facsimile. When certain of these modes are used in conjunction with radio, they are referred to, for example, as radioprinter, radiotelephone, and radiofacsimile. Some are briefly discussed below to facilitate their understanding.

In the first of these, Morse, the information to be transmitted is changed to an electrical form consisting of varying durations of current—or no current—referred to as "dots," "dashes," and "spaces." The dots and dashes can be produced manually by an operator using a telegraphic key, or automatically by electromechanical means. The average manual Morse operator sends about 15 to 25 five-letter groups (or words) a minute; superior operators, with a more complex hand key known as a semi-automatic key or "bug," transmit from 25 to 45 or even 50 words per minute. With automatic Morse, much higher speeds are possible.

There are a number of different "Morse codes," although the most common is known as International Morse Code, which is used for sending communications in all languages having alphabets based on Roman characters. The 26 letters of the English alphabet are represented, as well as some special characters, the numerals, and punctuation marks. Special Morse codes have also been established for other alphabets which do not so closely conform to the Roman alphabet, but similar sounds generally have similar Morse equivalents; included in this category are Greek, Russian (Cyrillic), and Arabic alphabets. The Japanese have a completely unique Morse code often referred to as the "Kana" Radio Code. Japanese text can also be expressed in Romanized form (Romaji) with the International Morse Code. The Chinese also use special codes. One is known as the "Ming Code" or Standard Telegraphic Code, another as PINYIN Romanization Form.

In the general development of communications techniques, effort was devoted to devising systems which were closer to being truly automatic than those employing Morse code. This is necessary since manual Morse does not readily lend itself to automatic handling, because of, among other things, the varying lengths of the characters and the different sending characteristics of individual operators. Also, in automatic Morse, manual transcription of tapes is slow, and automatic relay of tapes presents problems which are more easily met in teleprinter operation.

The modern day result of this effort is the teleprinter, which makes use, basically, of a typewriter keyboard in sending and a printing unit in receiving. Both are usually, but not necessarily, incorporated into one piece of equipment. Thus, typing skill rather than knowledge of Morse code is the basic operator requirement. In teleprinter operation, characters are represented by various combinations of impulses and absences of



This teleprinter, the Model 28, is capable of operating up to 100 words a minute. It can be operated manually or automatically to send or receive.

Delivery Distribution Points (DDP) contain many teleprinters to distribute incoming traffic to internal NSA/CSS recipients.

impulses, or marks and spaces, each, unlike Morse code, of equal length. These marks and spaces are commonly referred to as bauds. Standard operation of teleprinters is in the 60-to 120-word-a-minute range, although they are capable of much slower and faster operation.

With respect to its capacity to handle large volumes of information rapidly, one of the limiting factors in the teleprinter has been its electromechanical functioning, such as the movement of parts of the distributor, carriage, etc. Systems based more completely on electronic action were subsequently developed for the rapid transmission of information in digital form—either in ordinary numerals or in some type of binary code. Known as data-transmission systems, they are principally for the transmission of information in some standardized, stereotyped, or proforma arrangement. Examples of these include sales and inventory information passing among widespread elements of large industrial complexes, space-tracking information passing from a rocket launch site to a computer center, and early warning information passing from a distant-defense line to an air-defense command center.[2]

In telephone communications, the vibrations of the human voice (or other sounds) are changed to comparable variations in an electric current. Thus, special "codes," in the sense that the word is used in teleprinter operation, are not required. In radio usage of telephones, these variations (at audio frequency) are used to modulate the carrier wave, which, after propagation and reception, is demodulated to reproduce the audio-frequency electrical variations. These variations are then used to produce the approximate duplicate of the original sound vibrations, in a loudspeaker or headset, for example. Although this entire process comprises a variety of complex steps, the originating and reproduced sounds occur almost simultaneously, the small time interval being measured in fractions of a second.

Another electrical mode for conveying information is called facsimile, which, although characterized by a variety of types, is basically a means of sending electrically a copy of an original still picture, such as a map, photograph, printed or written page, and the like. Facsimile systems are widely used by press services, and are finding much use in business and industry. Most systems involve a line-by-line scanning of the original picture by a photoelectric cell, which converts whites, shades of gray, and blacks into varying electric current. In radio usage, these variations are used to modulate the carrier waves, which, after propagation and reception, are demodulated to duplicate the original electrical variations. Then, by any of several methods, these variations are used to reproduce, through synchronized line-by-line scanning, the lights and darks of the original picture.

Some other devices and systems of electrical modes of communications include the Hellschreiber, by which letters are transmitted electrically by a type of baud-based signal and reproduced on paper tape in the form of closely spaced inked lines; telemetry; and television.

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[2] A feature of this type of system is the visual display of the information at the receiving end, as, for example, aircraft positions on a radar screen.

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