# DIGITAL SIGNAL PROCESSING

# <u>FINAL REPORT</u>

# "FREQUENCY SPECTRUM; IT'S MEANINGFULNESS AND ENGINEERING APPLICATIONS"

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**EMMANUEL OSEI-MENSAH**

**M.Sc. (COMMUNICATION AND INFORMATION ENGINEERING)**

## INTRODUCTION

The energy created by electromagnetic radiation is generated from the forces exerted by the variable fluctuations of magnetic and electrical force fields emanating at right angles to each other traveling at the speed of light. These electromagnetic disturbances create waves which can be measured and which occur or pulse at different rates or frequencies each second. A frequency spectrum is a method of classifying, by their commonly understood names, the discrete and unique elements of all electromagnetic occurrences in terms of the frequency of the radiated energy induced each second. Radio waves, television broadcasts, X-rays, microwaves, and infrared transmissions are all electromagnetic radiations whose essential attributes can be defined and identified by the frequency or amount of radiation each type produces.

Frequency is defined as the number of complete electromagnetic energy wave cycles that occur each second. The international unit of measurement used to describe one cycle is 1 hertz (Hz). Since each portion of the electromagnetic spectrum has a telltale frequency signature, it can be identified by means of a frequency spectrum analyzer that is capable of accurately measuring the wave cycles per second of the particular electromagnetic phenomenon under observation.

Each of the varied forms of electromagnetic energy occupies a designated place on the frequency spectrum. The electromagnetic continuum, as expressed in terms of the frequency or the intensity of radiation emitted by each distinct segment, ranges from $10^6$ Hz up to $10^{25}$ Hz. Radio waves occupy the low end of the frequency spectrum whereas radioactive gamma rays occupy the high end. The frequency range encompassed by the electromagnetic spectrum is immense. Frequencies generated by radio transmissions and those produced by visible light vary by an order of magnitude of a million billion.

The frequency spectrum for radio transmissions is further classified into ranges of frequencies or "bands," both as a means for minimizing interference as well as for sharing bandwidth among multiple users. The International Telecommunications Union Agreement allocates certain ranges of radio transmission frequencies so as to minimize interference in the shortwave radio spectrum. The high frequency bands are allocated among international shortwave broadcasters, amateur radio operators, and marine radio communications.

## DEFINITIONS

The frequency spectrum of a time domain signal is a representation of that signal in the frequency domain. The frequency spectrum can be generated via a Fourier transform of the signal, and the resulting values are usually presented as amplitude and phase, both plotted versus frequency.

The radio-frequency spectrum is increasingly in demand from a large and growing number of services such as fixed, mobile, broadcasting, amateur, space research, emergency telecommunications, meteorology, global positioning systems, environmental monitoring and communication services - that ensure safety of life on land, at sea and in the skies.

Frequency spectrum is very meaningful because its study has brought about enormous development in telecommunication, biomedical, sound and other important engineering areas of life. It provides much information in bandwidth utilization and how it can be improved to make fast, reliable and large-data communication a realization.

Spread spectrum is a form of wireless communications in which the frequency of the transmitted signal is deliberately varied. This results in a much greater bandwidth than the signal would have if its frequency were not varied. Most spread-spectrum signals use a digital scheme called frequency hopping. The transmitter frequency changes abruptly, many times each second. Between "hops," the transmitter frequency is stable. The length of time that the transmitter remains on a given frequency between "hops" is known as the dwell time. A few spread-spectrum circuits employ continuous frequency variation, which is an analog scheme.

It would be suitable to define frequency spectrum hopping technique so as to understand the applications involving the hopping technique.

Frequency-hopping spread spectrum (FHSS) is a method of transmitting radio signals by rapidly switching a carrier among many frequency channels, using a pseudorandom sequence known to both transmitter and receiver. It is used as a multiple access method in the frequency-hopping code division multiple access (FH-CDMA) scheme.

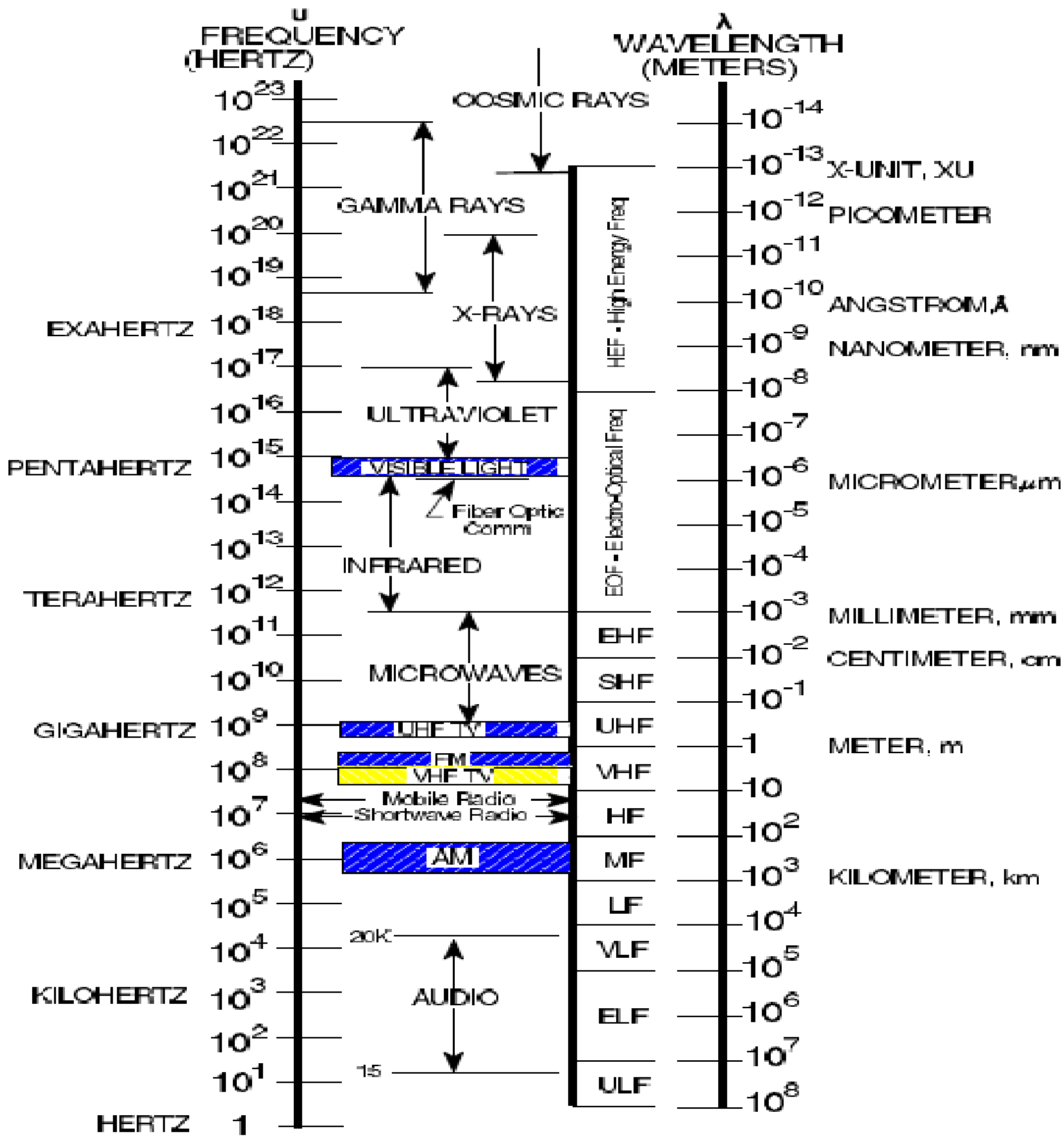


FIGURE: Electromagnetic Radiation Spectrum

## APPLICATIONS

- ❖ Application of frequency spread spectrum to geographical inversion problem.

In this application, Direct Sequence Spread-Spectrum techniques in conjunction with slow Frequency Hopping is applied to the estimation of acoustic wave propagation times in a geophysical medium. Instead of measuring travel-time via manual (visual) estimation of the direct-path arrival time of a one-shot disturbance sent from the source to the receiver, travel-time by establishing a Direct Sequence Spread-Spectrum Minimum Shift Keying link between the source and the receiver is measured. By sending timestamp data between the source and the receiver over this spread-spectrum link, travel-times can be calculated. In order to combat the problem of false locking of the Spread-spectrum system on strong indirect-path waves, the center frequency of the spread spectrum signal is frequency-hopped and the travel-time via the decision algorithm of "plurality rules" applied to the travel-times computed at each center frequency is calculated.

Many geophysical surveys are based upon measuring the travel-time of acoustic waves through a geological layer. The travel-time is an indication of the geological properties of the medium through which the acoustic waves propagate. When travel-time measurements are collected over a 2D grid, the composition of the interposing geophysical layer can be estimated though an inversion algorithm, in manner very similar to how medical imaging is done with the aid of the inverse Radon transform. Thus, acoustic travel-time measurement is a widely used tool in oil and gas exploration surveys. The conventional approach to travel-time measurement in geophysical surveys is based on generating a “one-shot” disturbance at the source and measuring its arrival time at receivers interspersed at the other end of the geological layer under investigation. This is prone to error due to various types of reflected and refracted waves which arrive at the destination points and interfere with the direct-path waves.

The use of spread-spectrum allows the measurement process to operate automatically, while frequency hopping the center frequency of the spread spectrum signal allows the receiver to discard erroneous results (arrived via false-locking on indirect-path head waves) via a simple "plurality rules" decision algorithm.

- Satellite application of frequency spectrum.

The problem of communication with Low Earth Orbiting (LEO) spacecrafts has led, in the past few years, to a number of significant break-through achieved in the field of spread-spectrum communications, coding systems and Data Relay Satellites (DRS). Concerning DRS, communications from/to LEO spacecrafts to/from ground station may be implemented via a Geostationary Earth Orbiting (GEO) Data Relay Satellite, assuring the LEO vehicles ($\leq$ 1000

Km orbit altitude) coverages for more than 55% of their orbit. Hence, two DRSs might in principle almost completely cover LEO orbits and a unique ground terminal can (control and) communicate with a number of LEO spacecrafts, exploiting a proper multiple access techniques.

However, some significant problems remain unsolved, as far as criticality of space-to-space communication links is concerned, as a lot of Radio Frequency Interference (RFI) might be present due to several LEO users transmitting in the same (or similar) electromagnetic direction, in addition to likely exceeding Power Flux Density (PFD) limitations on the earth surface. Hence, the use of Spread Spectrum (SS) modulation in the space-to-space link is widely considered to limit PFD, at least for low data rate channels (some tens-to-several hundred Kbps). This also led to some advantages in terms of protection against RFI, and the possibility of using the spreading codes to implement effective Code Division Multiple Access (CDMA) to the Satellite. Direct Sequence (DS) Spread Spectrum has been universally utilized for such applications, although somehow limited by the “near-far” effect.

With Frequency Hopping, timing requirements are not so stringent, as in DS spread spectrum signals. In addition, frequency synthesis techniques and associated hardware have been developed that make it possible to frequency hop over bandwidths that are significantly wider than those currently possible with DS systems; as a consequence, larger processing gains are possible with FH. The RF bandwidth available for a FH network is slotted into sub-bands or frequency "bins", where the signal is present for short time intervals called hop or “dwell” intervals. The RF signal from a given transmitter is hopped from slot to slot by changing the carrier frequency at certain points in time called hop epochs.

Furthermore, in order to optimize the bandwidth occupancy of the hopped signals, the bandwidth of frequency slots should be arranged in such a way to fill-in the entire bandwidth with the maximum number of frequency slots compatible with the tolerable number of "hits" among different users.

## CONCLUSION

Frequency spectrum engineering (signal spectrum analysis) is an essential signal engineering branch that has led to technological advancement in these past years. Signal spectrum services has led to the secure, manageable and protective applications. The study presented the definition of this kind of engineering and its essentiality, plus two important examples or applications of frequency spectrum.

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