Plasma, Cosmic Noise, Heterodynes and Harmonics

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Abstract—Two parallel electromagnetic waves intermixing in a plasma will produce a new single wave that contains all the frequency attributes of the two original waves, plus sum and difference frequencies. To retain all the original attributes requires that the two mixing waves have the same polarity, are coplanar and collinear. The perfect alignment occurs in vacuum tubes and semi-conductor devices used to produce heterodynes. Any deviation from the perfect alignment will change the EM wave intermix process such that both EM waves are altered and they will continue on in their original direction of propagation.

Introduction

Radio astronomy had its beginning in the early 1930s when Karl Jansky identified the general source for cosmic noise.[1] After the Jansky report was published in 1932, Grote Reber built a parabolic radio antenna along with associated receivers. Using proper astronomical terms, Reber published the first radio map of the cosmos in 1940, and again in 1944, titled "Cosmic Noise."

We are immersed in an ocean of electromagnetic (EM) emissions consisting of many frequencies that are all inter-mingled. A small part of this ocean of EM frequencies are artificially produced by man-made devices. The bulk of the EM frequencies are produced by natural processes, some local to Earth and our solar system, but the majority come from outside our solar system. Included in these EM frequencies is *cosmic noise*, which appears across the radio spectrum at discrete frequencies in the form of sharp pulses. The broad spectrum presence of cosmic noise has not had a reasonable explanation. The mechanism for the broad spectrum of cosmic noise pulses is covered in the material in this text.

A receiver is used to extract single frequencies from the intermixed broad spectrum of EM frequencies. A radio receiver is essentially a variable frequency filter. The dial or display indicates the frequency of the EM emission that will be accepted by the receiver filter process.

A receiver requires a sensor element to detect the presence of EM waves with a specific length. For the radio spectrum, the sensor element is referred to as an antenna. Antennas require different sizes to optimally detect the presence of specific sized wavelengths. If an antenna is not the proper size or is not aligned with the incoming direction of the EM wave, the receiver will have difficulty in detecting a relatively strong signal. The range of EM frequencies that can be detected is limited by our ability to design sensor elements for the very low and very high frequencies.

Another feature of all receivers is the automatic gain control (AGC) circuit. A receiver bandpass can contain many signals where the amplitude of the composite can vary over a large dynamic range. The AGC circuit responds to the highest amplitude signal within the bandpass by controlling the level of gain in the circuits that amplify the incoming signals. The purpose of AGC is to keep the amplifier circuits within linear parameters. The process causes weaker signals to be diminished such that they will not appear in the output.

An individual fundamental EM wave can contain within its waveform more than one frequency, and it requires multiple antennas and receivers to properly detect them. Some radio telescope sites are frequency restricted by their antenna systems.

EM waves can be altered when they traverse through a plasma.

Plasma in Space

The term *plasma* to describe an ionized gas was started in 1927 by Irving Langmuir. There are an abundance of plasma environments in space that will permit EM wave interaction. A plasma can consist of electrons and ions. A plasma has a number of characteristics that are density and frequency dependent.[2] A plasma that is within the influence of a magnetic field will have different characteristics depending upon the strength of the magnetic field and plasma density.

To establish baseline characteristics, studies assume that a plasma is uniform. There are conditions in space where a plasma is not uniform, even above the Earth.[3]

Radio astronomers use the term *dispersion measure* (DM) to describe the interstellar plasma or interstellar medium (ISM) in which EM waves must traverse from distant sources to a detection point.[4] The Cordes paper states, "We must take into account the distribution of electrons in the local ISM, and we require "clumps" and "voids" of electrons, mesoscale structures distributed throughout the galaxy on a large number of lines of sight in order to produce reasonable agreement with the observations.'

In space, when two fundamental EM waves having different wave frequencies travel through the same DM column, it is reasonable to expect that these waves will interact if the DM column passes through a plasma with sufficient density. When the resulting wave contains widely separated sum and difference frequencies, some could be deviated from the DM column by frequency related diffraction.

There should be denser plasma areas toward the center of our galaxy. With a denser plasma and the proximity to stronger galactic magnetic fields, plasma waves are probably being produced in multiple areas of the plasma. "In many cases the plasma or plasma waves can generate waves at frequencies that are very high in frequency compared to the highest characteristic frequency of a plasma. In this case the waves are electromagnetic and can propagate away from their source with little interaction with the surrounding medium. These high frequency waves are often referred to as radio waves."[5] In the plasma near the core of the galaxy, there could be numerous plasma related EM waves crisscrossing the galaxy and they could have very large magnitudes.

Simple and Cascading Heterodynes

Heterodynes are produced when two EM waves interact in the non-linear medium of a cloud or stream of electrons, a plasma. The heterodyne principle was identified in 1901 by R.A. Fessenden when all radio transmitters were spark gap (electric arc) based.[6] The first arc based heterodyne circuits were unstable. The vacuum tube was invented in 1904, but they were not used to artificially produce heterodynes until 1913.[7] Solid states devices are commonly used now.

The heterodyne process produces sum and difference frequencies. In the simple case of two interacting EM waves, f_1 and f_2, they intermix to produce f_3, the sum of f_1 and f_2, and f_4, the difference between f_1 and f_2. All four frequencies are present in the resulting EM waveform.[8] The power level of the resulting wave is the sum of the power levels of the two original EM waves. This complex wave contains multiple frequencies and can then interact with another wave having a different fundamental frequency and produce more heterodynes. The resulting waveform with its added heterodynes will be even more complex. This can happen repeatedly. There is no limit in how many frequencies can be impressed upon a specific fundamental EM wave. After a few interactions, it will be difficult to ascertain the frequency of the original interacting waves.

The simple heterodyne case described above is where two interacting waves have the same polarity and are aligned in space in the same propagation direction. This occurs automatically in vacuum tubes and solid state devices used to produce heterodynes. A heterodyne will be at a lower and a higher frequency than the original fundamentals and the frequency of the heterodynes are predictable if you know the fundamental frequency of both original waves.

In a plasma, when there is a deviation from the same propagation direction, the intermix process will truncate the waves of every frequency contained in the composite waveform. Both intersecting waves and all their components will be altered and continue on in their original direction of propagation. Each wave probably have an added sum and difference frequency. As the angle of incidence increases, the truncation will produce wave segments so short they will appear as static or cosmic noise. The process can be referred to as *non-parallel heterodyne action*.

A radio astronomer will not know if a signal detected at a specific frequency is that of an unaltered fundamental wave or that of a frequency residing on an altered fundamental wave. An unaltered wave would be detected only at the fundamental frequency. An unaltered fundamental EM wave may not exist in space.

Some radio telescopes, with suitable antennas and multiple receivers, have identified near identical pulses that occur at multiple frequencies.[9] The first sentence of the *Introduction* of the Lewandowski paper states, "The phenomenon of interstellar scattering of pulsar radio signals has been extensively studied for almost 50 years since it was identified (Scheuer 1968)."

The same plasma rich region near the center of the galaxy that provide the non-linear environment that produces heterodynes will also produces harmonics.

Harmonics

EM waves traversing through the non-linear medium of a plasma will produce harmonics. Harmonics are integer multiples of the fundamental frequency. If you know with certainty that a distant radio source is a fundamental, and that wave has traversed a plasma with a sufficient density, you can determine where harmonics would appear in the spectrum. It must be considered that diffraction could cause harmonics with very high frequencies, relative to the fundamental frequency, to defract from the DM viewing column.

Harmonics are impressed upon the fundamental waveform as are heterodynes. The manner in which a receiver functions as a variable frequency filter gives the impression a harmonic or heterodyne is the fundamental frequency of a waveform. Multiple receivers will permit the detection of harmonics and heterodynes if the harmonics and heterodynes have a sufficient power level.

The non-parallel interaction of two waves will truncate harmonics in the same manner as heterodynes.

Conclusion

The concept of heterodynes is taught as if the only place they can occur are in electronic devices that are used to produce heterodynes.

In space, the non-parallel interaction of EM waves is the rule rather than an exception.

When a unique spectrum signature is observed at multiple frequencies, heterodynes and harmonics should be considered. It cannot be assumed the highest or lowest frequency being detected is that of the fundamental frequency of the original EM wave source.

Current texts do not properly explain how the extremely short pulses called cosmic noise and the static accompanying lightning strikes are actually produced. It is suggested this is the result of multiple EM waves intermixing at many different angles of incidence. Multiple truncations of the fundamental, heterodynes and harmonics of a wave will eventually appear as sharp pulses at many frequencies.

For teaching purposes, a mathematical algorithm is needed to illustrate the wave form truncation that is produced when two fundamental EM waves, without heterodynes and harmonics, interact at various angles of incidence. The algorithm could present the frequency products in the spectrum format used in the Lewandowski paper. That format would show the EM wave truncation.

If there are galactic EM sources that emit just pulses, it will be difficult to identify them from EM waves that have been truncated by non-parallel EM wave mixing.

Radio astronomers need to determine whether a specific frequency they are detecting is a fundamental, a harmonic or a heterodyne.

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