Plasma, Cosmic Noise, Heterodynes and Harmonics

Frank H. Makinson

Abstract—The bulk of the electromagnetic (EM) waves produced and propagating throughout the universe are created in plasmas that are within the influence of a magnetic field. Every naturally produced EM wave will have multiple frequencies impressed upon their waveform during their initial creation and interactions within a plasma. The interaction of non-aligned electromagnetic waves within a plasma is not discussed in the literature and this interaction is the probable cause for cosmic and radio noise. Cyclotron particle motion in plasma tubes will produce helical electromagnetic waveforms. These waveforms will present a variety of characteristics at a receiving site depending upon the radius of the helical waveform, distance and viewing angle relative to the center of the helix. Incorrect conclusions can be made not knowing an electromagnetic waveform is helical with a radius.

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." All scientists before this time were unaware of the presence of radio waves coming from the cosmos.

It is necessary to note when certain things related to EM waves were known. James Clerk Maxwell formulated his equations that described the characteristics of electric and magnetic fields in 1864, and he stated that light was an EM wave. Ions were discovered by Svante Arrhenius in 1884. In 1886 Heinrich Hertz demonstrated that EM waves propagate through air. Electrons were identified by Joseph J. Thomson in 1897. The magnetic moment of the electron was confirmed by Otto Stern and Walther Gerlach in 1922. An ionized gas was referred to as a plasma by Irving Langmuir in 1927.

We are immersed in an ocean of EM emissions consisting of many frequencies that are all intermingled. A small part of this ocean of EM frequencies are artificially produced by man-made devices. The bulk of the EM emissions 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 emissions 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. A proposed mechanism for the broad spectrum of cosmic noise pulses is presented in this paper.

Electromagnetic (EM) waves are created by the motion of charged particles. The textbook description of how propagating EM fields are created is essentially correct where an alternating current and a metallic conductor are involved. The early researchers that used an electric arc to produce propagating EM fields were unaware of how charged particles interacting within a plasma that had an associated magnetic field created EM waves.

A plasma presents a non-linear medium to EM waves.[2-3] There is always a magnetic field associated with an electric arc that produces a plasma. When Heinrich Hertz demonstrated that EM fields could propagate through air, everyone in that era was unaware of the existence of the electron and their role in producing propagating EM waves. Hertz's instrumentation setup primarily produced EM waves with transverse polarization and he demonstrated how he proved this polarization. It is the orientation of the EM wave electric field to a reference plane that is used to define polarization. The pictures of his laboratory setup suggest most of his experiments were conducted in the *near-field*. [4] (Fig. 2)

Currently, there is a basic unanswered question concerning the manner in which the polarization of an EM wave is created, which is, "Does the magnetic moment of electrons and ions influence the polarization of propagating EM waves?”

Heterodynes and Harmonics

The presence of harmonics, heterodynes and the characteristics of radio receivers and associated antenna systems present major challenges to radio astronomers in identifying celestial radio source characteristics. Heterodynes and harmonics are two products of EM wave interaction in a plasma. Basic physics and electrical engineering textbooks identify the frequencies produced by heterodynes and harmonics are but not how the plasma interaction creates these frequencies.

The textbook descriptions of the heterodyne process do not state that the two interacting waves must be perfectly aligned and have the same polarization and propagation direction. This alignment is necessary to retain all of the characteristics of the two original waves in the resulting single wave. The resulting single waveform contains the sum frequency and difference frequency of the two original waves.[5] You now have one wave that, as a minimum, exhibits two frequencies on its waveform. The power level of the resulting wave is the sum of the power levels of the two original intersecting waves, but this is distributed between the two frequency components. This explanation is associated with the electronic devices which are used to create heterodynes and the devices provide perfect alignment. In space, in a plasma, a perfect alignment would be an exception and more than two EM waves could be interacting at the same time.

Harmonics are produced when an EM wave passes through a sufficient density plasma. Harmonics are integer multiples of the frequency of the fundamental wave and all these frequencies are embedded upon the original waveform. Depending upon the fundamental frequency, its magnitude and density of the plasma, harmonics have been detected up to 20 multiples. Heterodynes can be produced at the same time as harmonics, which adds to the complexity of the resulting waveforms. Harmonic action distributes the power to harmonic frequencies, diminishing the power of the fundamental. How the plasma EM wave interaction produced harmonics was never explained. A recent study has identified a plasma mechanism that creates harmonics.[6] The research was with a man-made plasma and it had specific conditions. The Lane report stated, “Note that there are no dc magnetic fields present in this system and references to magnetic fields are always to the time varying fields.” and “... the magnetic field is produced primarily by currents due to electron movement rather than to the displacement current.” Research reported in ref. (11) of the Lane paper originally identified the plasma mechanism that is associated with harmonics.

Radio Static and Cosmic Noise

Cosmic noise, natural local radio static and artificially produced radio static are all related to how EM waves interact within a plasma. Textbooks cite some sources for local radio noise, such as lightning bolts, motor commutators or automotive ignitions, but do not describe how these sources create EM emissions that appear as sharp pulses over a broad spectrum of frequencies. There is a common element associated with locally produced radio noise, a plasma and a magnetic field. All electric arcs create a plasma and the current path in the arc creates a magnetic field.

The first part of the process that produces radio noise is the movement of charged particles, both electrons and ions. Once the EM waves are produced they will be propagating in all directions within the plasma and they will be subject to the harmonic and heterodyne processes, which provide a synergistic process that expands the spectrum frequency coverage. The duration and size of the plasma will have a relationship to the spectrum coverage and magnitude of the noise. The wave-to-wave intermix process in a plasma, which can occur at all angles, will produce additive and subtractive processes that create severely altered waveforms.

In a plasma, non-aligned wave interaction would be the rule rather than the exception. The misalignment can be any angle and different wave polarities add another misalignment factor. The wave interaction in a plasma is a synergistic process with waves altering waves altering waves. After multiple interactions the resulting waveforms will contain a profusion of spikes which can appear over a broad spectrum range.

Plasma

Plasma research is identifying new characteristics. The characteristics of a plasma vary relative to the density of the plasma and the strength of an associated magnetic field. Radio astronomers often use the term quasi-static when referring to a magnetic field as opposed to a static magnetic field. In space, the magnetic field can be that of a planet, a star or a galaxy. Our ionosphere is a plasma and it depends upon the plasma density, frequency of the EM wave and the angle of incidence whether a wave will be reflected or pass through it. There could be diffraction effects.

Plasma waves, sometimes referred to as Langmuir waves, can be produced in a plasma. These waves are the result of the interaction between the charged particles that compose the plasma. The Kurth paper stated, “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.” and “Another common characteristic frequency of a plasma is called the electron cyclotron frequency. If the plasma is embedded in a quasi-static magnetic field, the charged particles will be accelerated in a direction perpendicular to the magnetic field causing them to move in a helix around the field lines.”

Ions rotate about the magnetic field in the clockwise direction and electrons rotate counterclockwise at a different radius.[7-8] These charged particles will move in a helix at their respective cyclotron frequency and produce helical EM (HEM) waveforms. There is no information on how HEM waves rotating in the same direction or counter-rotating interact. A different antenna structure is required to properly detect helical waves. Depending upon the radius of the source, viewing angle and distance, a conventional antenna may detect just a single pulse every cycle.

The plasma ducts around the Earth vary diurnally.[9] The Loi paper chose to use the term density ducts rather than plasma ducts. The plasma ducts have a higher density toward the outside of the ducts which produce an EM wave containment channel. Whistler waves are produced and propagate within and from them. There should be plasma ducts around the Sun and there are dramatic energy events on the Sun that would effect the characteristics of its ducts. The whistler-like waves produced therein may have very low frequencies, sub-Hz, but there should be harmonics that our current instruments can detect. They could be difficult to identify because of the other radio noise produced by the Sun.

There are plasma concentrations throughout the galaxy.[10] The Cordes paper stated, 'We must take into account the distribution of electrons in the local ISM (Interstellar Medium), 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.' There should be dense plasma formations closer to the center of our galaxy that are in the influence of its magnetic field.

The term *dispersion measure* (DM) defines the plasma density in a viewing column from a source to a viewer or receiver. The DM varies depending upon viewing coordinates. Our closeup viewing position relative to planetary and solar EM emissions allows more variables to be detected. Our relative viewing position to pulsars and quasars is very remote, which limits the resolution and the number of variables that can be observed. Pulsar pulses are all about plasmas.[11] The Mahajan paper emphasized the need for a very strong magnetic field, which would be the environment present with plasma ducts associated with our galaxy core.

Plasma waves have longitudinal polarization. No references were found that discuss the effect plasma wave longitudinal polarization has on the electrons and ions that are producing EM waves. For EM waves, longitudinal polarization occurs when the electric field vector is parallel with the direction of propagation. This is important when considering the source power of celestial EM waves, as an EM wave with longitudinal polarization decays with distance by 1/r, whereas transverse waves decay by $1/r^2$. Eugenio Beltrami described longitudinal polarization using Maxwell's equations, and they are referred to as Beltrami fields. A Beltrami field produced on a radius is not self-cancelling. A HEM waveform could have both transverse and longitudinal electric field polarization. Plasma ducts may not be perfectly round which could result in an elliptical wavefront.

The apparent circular polarization observed from specific radio sources could be indicative of either the transverse or longitudinal portion of HEM waveforms. Most antennas designed to detect transverse polarization will not efficiently detect longitudinal polarization. Helical antennas would detect longitudinal polarization, but not optimally. To properly identify the presence of a HEM wave will require an antenna system and signal processors that can extract the angular character of that waveform. This will require major changes in antenna structures and the signal processing system.

The polarization of celestial radio signals may not be that of the original source.[12-13] Until we have radio telescopes that are beyond the Sun's heliosphere and its plasma ducts, we will not be able to eliminate local solar system polarization changes of distant EM sources. The polarization detected at the antenna cannot be determined if the antenna feed lines alter the polarization; see footnote in ref. 12.

Glitches, Downshifting and Multi-Frequency Scattering

The terms *glitches, downshifting and multiple frequency scattering* are associated with pulsars. Pulsars have been found that have pulses that vary significantly, slower or faster. This phenomena is referred to as *glitches*, sudden changes in pulse period, and many pulsars present this anomaly, some repeatedly.[14-15] The Crab and Vela nebulae are outside of the galactic plane where most pulsars are found. These nebulae are significant plasma sources, each has a magnetic field, and their pulsar pulses exhibit *glitches*. Originally, pulsars were thought to be completely constant because their mass would keep them spinning with no variations.[16]

The phenomena of multiple frequency scattering and downshifting does not follow the classical heterodyne or harmonic theory. Downshifting would be the inverse of harmonics, which means there has to be a plasma characteristic that produces downshifted frequencies.

Multi-frequency scattering is observed with many pulsars.[17-18] The Lewandowski paper did not give the specific frequencies of the observed downshifted frequencies, just the bands in which they appeared. The Eilek paper provided specific frequencies and the waveforms are not a well defined single pulse shape, but appear like the result of wave mixing. The introductory sentence of the Eilek paper states, “Pulsar radio emission is not well understood.”

It is quite probable that a vast number of plasma waves are being created and interacting with EM waves in the plasma ducts near the galaxy core. There is a probability that some of the EM waves produced in these plasma ducts could be propagating toward our viewing location. If the resulting EM waveform is a helix or elliptical with a large radius, we may detect just a single pulse with a specific repetition rate. The Langmuir waves produced in very large plasma structures could have very long periods and these may be related to the periodicity of the glitches.

The presence of multiple frequencies on a waveform presents interpretation problems for radio astronomers. A radio receiver functions as a variable frequency filter. When an antenna is pointed toward a distance source, has the correct dimensions for the detected frequency and the same polarization as the distant signal, optimum signal detection will be achieved. However, a radio astronomer will not know if that signal being detected at a specific frequency is a fundamental, harmonic, heterodyne or a downshifted frequency. Multiband receivers and broadband spectrum displays help contemporary radio astronomers to identify a signal that appears at multiple frequencies.

There is no assurance that the strongest signal received is the fundamental, as that could mean that particular frequency has a better match to the antenna parameters and/or the frequencies on the waveform have been altered in the DM process.

Conclusions

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

Plasma duct phenomena near our galaxy core that produces helical waveforms can replicate what radio astronomers theorize as a rotating object emitting repetitive pulses. It is well known that electrons and ions follow a helical path within a plasma that is in the influence of a strong magnetic field, but it is not known why it is never mentioned the helical particle motion will produce a helical waveform with a radius.

A pure unaltered naturally produced fundamental EM wave having no added heterodynes or harmonics impressed on its waveform may not exist in space.

It is quite possible that quasar radio signals are a multitude of pulsar-type pulses that cannot be resolved to individual sources because of their great distance. The distance suggests that the quasar radio signals being detected have longitudinal polarization.

Text books need to be updated to explain how cosmic noise and radio noise are produced in a plasma in space where non-parallel interaction of EM waves would be the rule rather than an exception.

For teaching purposes, three mathematical algorithms are needed to illustrate the waveform alterations that are produced when two fundamental EM waves interact at various angles of incidence and with different polarizations. One algorithm would illustrate conventional transverse waveform interaction and the second helical waveform interaction. The helical algorithm would have to accommodate different helix radiuses and transverse or longitudinal polarization and a mix thereof. The third algorithm would illustrate the interaction between transverse EM waves and HEM waves.

An answer is needed to the question, “Does the magnetic moment of electrons and ions influence the polarization of propagating EM waves?”

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