Cargo Cult Science – Electromagnetic Harmonics and Heterodynes

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Abstract – The process that produces harmonics and heterodynes are assumed to be well understood. The textbook definitions of these two terms are being tagged herein as *cargo cult science* because they are incomplete. Harmonics and heterodynes are an effect created when electromagnetic waves interact within a plasma of charged particles. The textbook descriptions of harmonics and heterodynes are based upon fundamental electromagnetic waves, sine waves that represent a single frequency, a special case. The textbook descriptions are based upon interactions that occur within electronic devices, which is a special case. For heterodynes, textbooks do not mention that the interaction within electronic devices are collinear, which is a special case. Radio astronomers are detecting signals coming from space that have spectral characteristics unlike anything taught in the textbooks. Contemporary radio astronomers would be the primary group of individuals that would be misled by the incomplete information provided in the textbooks.

Introduction

Richard Feynman introduced the term *cargo cult science* to the 1974 graduation class of the California Institute of Technology. Cargo cult science is a process that gives the appearance of the scientific method. The actions performed that created the term *cargo cult* were the result of conclusions based upon *incomplete information.*

The textbook descriptions of harmonics and heterodynes are based upon fundamental electromagnetic (EM) waves that represent a single frequency, a sine wave. One EM sine wave interacting within a non-linear medium results in the production of harmonics, which are integer multiples of the frequency of the original frequency, f_1, producing $2xf_1$, $3xf_1$, $4xf_1$, etc. When two fundamental EM sine waves with different frequencies, f_1 and f_2, interacting jointly and perfectly aligned within a non-linear medium creates heterodynes, the sum of the two frequencies, f_1+f_2, and the difference between the two frequencies, $f_1–f_2$.

The heterodyne principle was developed by Reginald Fessenden in 1901 using a tetrode vacuum tube in an electronic circuit called a *mixer.* The textbook is describing the basic single frequency waveforms required to create the heterodyne frequency products. The textbook does not state that the two frequencies are interacting in a collinear manner, because that is the only type of interaction that can occur in a contemporary mixer circuit.

Collinear interaction is a special case. It wasn't known at the time the heterodyne principle was identified that collinear interaction was a special case. It was not known in 1901 that EM waves, other than light, were being produced and propagating throughout the cosmos. Collinear interaction within a plasma in space would be a rare event in comparison to noncollinear interaction. It would be expected that EM waves interacting within a plasma in space could have many different crossing angles.

A non-linear medium can be gaseous plasma in space, the plasma produced inside a vacuum tube or the solid-state plasma of semi-conductors. Conductors function as a linear medium even though they contain mobile charged particles, valence electrons. Semi-conductors are in a perpetual state of charge imbalance, having a constant disparity between positive and negative charges, holes versus electrons, which creates the non-linear medium.

Radio astronomy did not exist until after the discovery of radio signals coming from space and the signal sources were identified using traditional astronomical coordinates.[1-3] Karl Jansky was a radio engineer whereas Grote Reber was a radio engineer and an amateur astronomer.

Radio astronomers are using the terms multi-frequency scattering to describe multiple frequencies that are observed in association with some pulsar signals.[4-5] The frequency spacing of the multiple frequencies observed cannot be explained by the textbook descriptions of harmonics and heterodynes.

Radio Receivers, Harmonics and Heterodynes

A radio receiver functions as a frequency selective filter to extract a particular frequency that is impressed on an EM wave, because an EM wave can contain a wide range of frequencies. Any EM waveform other than a fundamental sine wave will contain multiple frequencies. Many individuals that use radio receivers are unaware of the terms harmonic and heterodyne and some of the signals they detect could be harmonics or heterodynes that are impressed on a particular fundamental signal. When widely separated frequencies interact within a plasma, it is possible that not all of the resulting signal products will be within the bandpass of a particular receiver.

The basic textbook explanation of the heterodyne process generally avoids stating that each of the two input signals involved in producing heterodynes also generate harmonics and a multitude of intermodulation products. These multiple frequency components are filtered out after the mixer, but this will not be the case when signal mixing occurs in a plasma in space.

Researchers have not properly described the differences between how electromagnetic waves interact within plasmas in space as compared to interactions in solid-state plasmas within electronic devices. Textbooks explain the basic conditions needed to produce harmonics and heterodynes, but do not explain how charged particles in a non-linear medium interact with an EM signal to create harmonics and heterodynes. The term collinear is never mentioned and plasma is rarely mentioned in the descriptive materials explaining harmonics and heterodynes.

Textbooks and associated technical literature do not mention the resulting EM waveforms produced by noncollinear interaction. Noncollinear EM wave interaction will be the general case for EM waves interacting within a plasma in space. It is expected that EM waves that interact at widely different aspect angles will produce signal products that have unusual amplitude displays and many could appear as severely *chopped* short pulses. This could contribute to what is termed *cosmic noise*.

Spectral broadening is a process where an EM wave with a single frequency or one containing multiple frequencies are broadened. The harmonic and heterodyne actions produce spectral broadening as does the Doppler effect. It is apparent that spectral broadening is being produced on a massive scale in plasmas throughout the universe. This suggests that harmonic and heterodyne production, as well as other processes that result in spectral broadening, are an important aspect concerning energy exchanges within the universe.

Radio astronomers using receivers that utilize the heterodyne principle must be aware that the circuitry itself can introduce unwanted signals. The voltage controlled oscillator (VCO) in a phase-locked loop (PLL) can produce sub-harmonics, and this is mentioned in the VCO specifications. The term *phase noise* is used to describe other unwanted frequency components that occur in the PPL. It is not known whether sub-harmonics can occur during EM wave interactions in plasmas in space or if it is just an artifact of a PPL.

Cryogenic cooled receiver amplifiers and mixers have reduced the thermo noise created within receivers allow researchers to identify signals that had been masked by that type of noise. A lower noise level will produce spectrum displays containing a larger number of discrete signals.

The characteristics of the spectrum identified by radio astronomers that was give the name *multi-frequency scattering* may be the result of noncollinear interaction of two or more EM waves. The process is similar to the heterodyne principle in regards to the frequencies produced, but just one of the main frequencies is being detected along with the added heterodynes and harmonics.

Conclusion

The textbook descriptions of the harmonic and heterodyne effects are deficient. Textbooks need to emphasize that the use of sine waves to present the basic theory is a special case applicable only to electronic mixer devices and associated circuitry, and that they produce collinear interaction. Unless introduced in a prior text, students need to be introduced to the terms solid-state and gaseous plasma and where they exist, and how their non-linear properties produce harmonics, heterodynes and intermodulation products.

Once the basics are presented, students need to be informed of the frequency products produced when EM waves containing more than one frequency interact within a plasma in space. It should be explained that interactions can occur in space at different intersection angles between EM waves having different polarity orientations.

Radio astronomers have created terms to describe their spectral observations of signals detected coming from celestial EM sources, one being *multi-frequency scattering*. It appears this term is a reflection of textbook deficiencies in presenting the theory of harmonics and heterodynes.

References

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