Cargo Cult Science – Electromagnetic Harmonics and Heterodynes

Frank H. Makinson

Abstract – The process that produces electromagnetic wave harmonics and heterodynes are assumed to be well understood. The textbook definitions of these terms are being tagged herein as *cargo cult science* because they are incomplete. The effects these term describe occur when electromagnetic waves, singularly or in combination, interact within a non-linear medium. The textbook descriptions of these terms are based upon fundamental electromagnetic waves, sine waves that represent a single frequency, interactions that occur within electronic devices and interactions that are collinear. Each of these interactions are a special case. Radio astronomers are detecting signals coming from space that have spectral characteristics unlike anything taught in the textbooks. The manner in which textbooks describe EM wave interactions in nonlinear mediums can result in incorrect interpretation of spectral signatures. Radio astronomers need to be aware that artificial modification of the Earth's ionosphere can modify the signals they are detecting coming from celestial sources.

I. 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 (intermodulation) are based upon fundamental electromagnetic (EM) waves that represent a single frequency, a sine wave. The fundamental is the lowest frequency component of a 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 $2f_1$, $3f_1$, $4f_1$, etc. The heterodyne principle defines the frequency products produced when two fundamental EM sine waves with different frequencies, f_1 and f_2, interact jointly and perfectly aligned within a non-linear medium to create heterodynes, the sum of the two frequencies, f_1+f_2, and the difference between the two frequencies, $f_1–f_2$. The heterodyne frequency set is incomplete because textbooks are identifying only the frequencies of interest needed to understand the heterodyne principle used in electronic *mixer* circuits. Intermodulation is the effect created when two EM waves interact within a non-linear medium and produce the frequency set $mf1\pm nf2$, (m,n=1,2,3,...). Textbooks do not point out the significant difference between heterodynes and intermodulation. 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.

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

Collinear interaction is a special case, but it was not known at the time the heterodyne principle was identified that collinear interaction was a special case. Additionally, 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 and polarity alignments.

Cross modulation produces the same frequency products as intermodulation. Cross modulation is an effect where the amplitude modulation (AM) of a stronger signal overrides the AM modulation of a weaker signal and this modulation will be impressed on all of the intermodulation frequency products.

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. Grote Reber was a radio engineer and an amateur astronomer.

Radio astronomers are using the term *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, heterodynes and intermodulation.

II. Radio Receivers, Plasma and Spectral Broadening

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 or intermodulation and that some of the signals they detect could be harmonics or intermodulation signals that are impressed on a particular fundamental signal. When EM waves with 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.[6] 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 intermodulation frequencies. The term collinear is never mentioned while the term non-linear is mentioned frequently. Plasma is rarely mentioned in the descriptive materials describing harmonics, heterodynes and intermodulation.

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 be a major contributor 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 intermodulation actions produce spectral broadening as does the Doppler effect. It is apparent that spectral broadening will be occurring on a massive scale in plasmas throughout the universe. This suggests that harmonic and intermodulation 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.

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 and more of the higher order frequency products of harmonics and intermodulation.

The characteristics of the spectrum identified by radio astronomers that was given the name *multi-frequency scattering* may be the result of noncollinear interaction of two or more EM waves within a plasma and this could be the Earth's ionosphere. The process is similar to intermodulation in regards to the frequencies produced, but not all of the frequencies involved in the intermodulation are being detected. The intermodulation can occur when areas of the Earth's ionosphere are being excited by strong EM radiation sources, which can be manmade.

III. Ionosphere Cross Modulation

The Luxemburg-Gorky (L-G) effect was originally discovered in 1933.[7] It was determined that the ionosphere above a high power short-wave radio station was producing cross modulation products when another broadcast station with a different frequency passes through the same area of the ionosphere. For a signal without modulation the interaction is simply intermodulation. Rather than refer to it by its 1933 name, the effect will be identified as *ionospheric intermodulation* (IIM) and it presents a serious problem for radio astronomers.

Since it was discovered that manmade radio signals could alter the ionosphere, there has been extensive research in this area.[8] A radio signal coming from space can be altered by IIM when it passes through an ionosphere area being stimulated by manmade radiation sources. EISCAT has multiple sites and multiple frequencies. From ref. (8), “The *D*-region is responsible for the vast majority of signal absorption that trans-ionospherically propagating radio waves experience, and the absorption process is highly nonlinear. Additionally, because the properties of the *D*-region ionosphere vary significantly with time, the level of absorption that radio waves experience is also highly variable.”

The ionosphere is being stimulated continuously by Earth based transmitters broadcasting over a broad range of frequencies with a variety of pulse and modulation characteristics, and all of these have the potential to produce the IIM effect. Some of these research transmitters produce exceptionally high power levels.[10] The HAARP facility was used in an attempt to duplicate the Luxemburg-Gorky effect.[11] HAARP transmitters were used to bounce low frequency signals off the moon, frequencies that are not supposed to be able to pass through the ionosphere. A radio astronomer will not know if the signals they are detecting from distant celestial sources have been altered in some way by an IIM effect. There are the space debris and military long distance radars. There are no radio astronomy telescopes above the ionosphere to eliminate the IIM effect.

Long before a signal from a celestial source has reached Earth, even if a signal source was originally generated as an EM wave with a single frequency, there is a high probability it will have been altered by harmonic and intermodulation processes as it and other waves pass through various concentrations of plasma. The resulting signals can be described as *celestial intermodulation* (CIM) products.

It cannot be assumed that all EM waves emanating from celestial sources are isotropic. There can be multiple waves involved in creating CIM products, but only those that have a propagation direction toward Earth can be detected. Radio astronomers do not know if they are detecting a distant signal within the main lobe or side-lobe of a radiation source.

IV. 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 these devices provide collinear interaction.

Students need to be introduced to the terms solid-state and gaseous plasma early in their basic physics education, where the plasmas exist, and how their non-linear properties produce harmonic and intermodulation products.

It needs to be taught that EM wave interactions can occur in plasmas in space at different intersection angles between EM waves having different polarity orientations. Multiple EM waves can be interacting, but not all of their propagation directions would be toward Earth.

Radio astronomers cannot assume, because of IIM, that all the signals they detect are coming from celestial sources. Radio astronomers must keep track all the frequencies used for ionospheric modifications, when they are radiated and the ionosphere sectors affected.

Radio astronomers will have to contend with CIM.

V. References

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