Improper Combined Transmitter Phase Alignment of HD Radio Transmitters and Amplifiers Causing Distortion Of The Data Resulting In Decreased Decodable Coverage

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PREFACE:
With the flailing push toward HD Radio, broadcasters have sought to increase the raw coverage foot print and perhaps the popularity of the radiated signal by increasing the radiated power. This increase in ERP is a mix of symmetric and asymmetric sideband energy increases. This is a common practice utilized by nearly every form of communication today. Better antennas, patterns and changes to the power levels in the sidebands, along with asymmetric energies, have all been tried as enhancements. Certain operations also demand combined transmitter systems in situations where losses, necessitate higher TPO's. In certain circumstances this elevation in Effective Radiated Power, (ERP) along with these other potential enhancements, are complimented by progressions in receiver technology. The Cellular communication technologies utilize extremely low transmitter output power (TPO) as well as extremely sensitive receivers that make use of the specialized Digital coding schemes that allow for inherent noise cancellation and effective data acquisition down to a range of -120dBm or greater. Unfortunately this utilization of the enhanced conditions of noise cancelling data and enhanced receiver technology is not really in use today in the broadcast market place. While chipsets for decoding HD Radio continue to improve, it is the receiver technology limited by the original coding method, along with transmitter deficiencies that forces limitations in the results. This Patent protected lack of progressive technology forces the realm of HD Radio to resort to brute force tactics, even if they may be fraught with problems that result in damaged, or destroyed Digital data. In contrast to the very forgiving Analog signals enjoyed still today, the average HD Digital coverage of a given station that is repeated across the United States is not in keeping with the mathematics of the output power being transmitted. Some of this lack of coverage and fade to fatal is assumed to be the Cliff Effect due to ERP limitations but is actually the fault of the coding scheme and channel bandwidth allocations that are adversely acted upon by antenna gain, patterns, parasitic radiators (intentional and unintentional) faulty combining methods, propagation and a host of other controllable and un-controllable factors. This paper contends that there is another side to these coverage issues.

BACKGROUND:

The accepted FM HD Digital format presently in use is a medium speed, moderate bandwidth, Digital word that is highly compressed and is given the disadvantage of only a fraction of the allocated channel bandwidth. Unlike the dramatic sideband splatter of the signal used in Amplitude Modulated (AM) HD Radio, the Frequency Modulated (FM) signal exhibits a much tighter control over the occupied bandwidth and sideband splatter. It is not the intent nor desire of this paper to dispute or criticize the encoding Digital format in use today for HD Radio. This paper is directed toward the electrical problems of generating the power levels, and antenna patterns needed for HD Radio. These are all pieces of the problem.

THE PROBLEM:

As FM HD Radio advances, various transmitting schemes have been devised. When first developed, the method of embedding the HD information on to a carrier, involved a method of signal generation in a common mode Exciter. This complex data generator created an output of the Analog signal as well as the Digital signal and sent them to an amplifier for eventual radiation from a common antenna. This common mode, being quite common (pun), is usually relegated to very low output powers. This paper acknowledges that there are presently advances being made in higher power output devices to improve upon the requirements for elevated ERP. This paper contends that this common mode, is a purist approach as a technique, and that this is the proper approach as the Analog information is pure, and the Digital information is also pure and uncorrupted. This common mode method is virtually completely corrupted by the application of amplification in Class "C" technology and seems to be unavoidable. Common mode amplification had been relegated to modified versions of Class "A" , "AB", or even "AB2" modes. These modes maintain the linearity required for amplification of the Digital word. High power applications initially meant discrete amplification and wasteful injection of energy so that a single antenna could be used. So many avenues of transmission were proposed all the way to discrete, interleaved and cross polarized antenna systems. The variations of the theme seemed nearly endless but the problems of combined transmitters never gets addressed beyond the "in phase" satisfaction of the reject loads.

THE METHODS:

In the early stages of development of higher output powers and elevated ERP conditions, the advent of multiple amplifiers came about. These methods can be divided in to two classes. Class one utilizes a dedicated Analog transmitter and a dedicated Digital transmitter. The method of combining the two signals and the method of delivery to the coaxial conductor or antenna is of no consequence to the range and coverage of the signal for this discussion. Method two utilizes a primary transmitter that continues to amplify the Analog signal as well as a Digital signal and then combines this with a transmitter that produces an Analog signal exclusively. The only casualty here is wasted electricity to accomplish the goal This second method is the object of this paper. The advent of having a transmitter amplify both the Analog and Digital signals simultaneously is considered to be a part of the Class two group.

Within the Class two group, a single amplifier that operates within a linear enough range to "faithfully" deliver the Digital word is the second purest form for non-destructive delivery of the Digital word. Combining these amplifiers is the issue. A single tube amplifier operating in a semi linear mode has demonstrated the ability to deliver a QOS (quality of signal) that is reasonably acceptable. Examination of heavily combined solid state amplification as well as multiple discrete transmitters (pairs) is a potential problem that this article addresses. It remains a mystery why this linear amplification has existed in the video realm since its inception but took many years of patent wrangling to be brought to the audio market in the vacume variety.

PROBLEMS AND SOLUTIONS:

With every problem in HD Radio, a solution is sought. Regarding higher TPO, the methodology of combining two transmitters seems the likely answer to the need, but it is the method that is the concern. Combining transmitters is as old as paralleling sources of any type of power. Westinghouse, Marconi, Edison and every genius of the early days fought this battle and the answer to the need for greater power was larger and larger generators of the desired signal. At some point (pending the genre) bigger was not achievable nor feasible and we fight this battle through today. The answer lies in combining generators of the signal of a like kind. The desired signal to be delivered should be identical in EVERY way from one source to another, no matter how many sources. (amplifiers) This led to the methods still in use today which require the alignment of the waveform of the desired signal. As this is largely accepted to be a sinusoid or sine wave (regardless of the frequency) this is not rocket science though it did have a certain flair way back there in years. This alignment of the carrier frequency sinusoid utilized in combined amplifiers in the Analog mode has been extremely successful for many years, and in the Analog mode, has apparently exhibited no audible adverse problems as far as any proof of performance has been concerned. With the time alignment of the FM modulation being mashed together, no audible or reasonably measureable distortions to the Analog have been presented.

As the alignment of the carrier wave sinusoid has the key factor to successful elevation of the TPO of the system, attention has been focused on this R.F. wave as the primary concern, and for the author, has been wrongly accepted to be the only concern.

The generated modulation and the recovered modulation take a back seat to this elevation in the R.F. TPO but do not seem to be adversely acoustically affected to a point of public concern, though there is indeed an actual alignment issue that can result in minor acoustic anomalies. When you have time, rotate out a wave from one transmitter to another 360 degrees at a time, note the time delay by indexing the carrier frequency and apply this time delay from the original or base wave to each successive rotation and see if the microseconds will or could have any audible effect on the sound that a human can hear, let alone that test equipment will measure reliably. The digital time slots do not remain in alignment, nor do they contain the same information.

ENTER THE PROBLEM:
Considering the lowly combined amplifier in the FM mode, the absolute time alignment of the sinusoid is achieved. This measure of success is the null of the reject load metering.
There are considerations of matching the relative power level, and the phase alignment of the sine wave. Proper cohesion of these considerations will yield a minimal reflected power from the method of combination as absorbed by the common reject load in a given stage.
Further consideration to the level of the reflected signal from the combining method includes, the distortion of the sine wave. The method of amplification is one source of this distortion as is harmonic interference and subsequent filtering. The embedded modulation is another. Is it strange to consider the modulation as a source of distortion?

ANALOG DISTORTIONS PREFACE:
Raising the proposal that each method of amplification will act differently upon the commonly generated, sole source sinusoid, (Exciter) exacerbated by the lack of symmetry of the componentry from these methods, creates the preface for the theory of this paper. Even with identical types of independent amplification, regardless of the method from hole filled crystalline structures to vacume devices, the time and phase differentials acting upon the sinusoid aggravated by the modulation data (Analog and Digital) will create elevated and complex distortions. According to Nyquist (and others) frequency response and distortion are a function of the carrier or sample method. Some license is taken to extrapolate the Analogy.

SUPPOSITION:
A carrier wave of 100mC is acted upon by a distortion (the modulation) of a frequency of no greater than 100Kc. (in the Analog consideration) This frequency split far exceeds the level of acceptable encoding for consideration. The embedment of the distortion (modulation) is of a frequency that appears to be of such inconsequence to the frequency of the carrier that measuring this resultant distortion is not given any thought. Any interaction of intermodulation distortion between the complex audio of the Analog modulation is seemingly of no consequence to the carrier wave and vice versa. This relationship exists whether the amplified signal is derived from a single high power amplifier (typically a tube) or multiple amplifiers (solid state) and the performance is usually perfectly acceptable though not technically perfect.

DIGITAL DISTORTIONS PREFACE:
As elevated TPO is a direct function of the technology of combined amplification as applied to purely Analog methods, the transferred thoughts of phase and power alignment transcend in to the HD application. Remember,,, the Analog impression on to the R.F. carrier is a mere fraction of the frequency, speed, and timing of each of the hundreds of individual data carriers that make up the HD Digital word. While the Analog impression of the modulation exists in a blink of time for so much longer, as it is so much slower than the Digital carriers, each complex waveform of the Analog, like the Digital information only exists once and is never repeated again, unlike the R.F. Carrier.

The use of solid state or vacume is considered moot so long as the mode of Class in “A”, “AB”, or “AB2” are observed. Strictly ruling out Class “C” still applies. If one accepts the premise that Analog, or Digital modulation is a form of distortion applied to the carrier wave, even though is it of little seeming consequence, the elevation of the apparent frequency of the modulation with the application of the Digital word begins to come in to play in a greater way.

While this Nyquist differential is still substantial numerically, the fragility of this applied modulation to one type of amplifier or the other, will still conform to the purist genre of thought so long as there is only one transmitter or amplifier.

Unfortunately with every solid state commercial transmitter on the market today, combining is a fact of life, even in single tube output configurations, the solid state driver IPA pallets are always combined. As with any application of Digital modulation, linearity is the key to successful decoding. The distortion free original modulation, regardless of any error correction must exist if the carrier wave is to perform its prescribed duty and travel any considerable distance, regardless of the method of conveyance. This is true if you really want a decodable signal at the other end while ignoring propagation issues.

A VARIATION OF TRAVEL:

The method of conveyance is not a part of the issue of this paper and is not relevant. While it is acknowledged that methods of conveyance exhibit anomalies of their own due to either electromechanical problems or electromagnetic perturbations, these are a secondary discussion to this theory. The methods of combination reviewed thus far can be construed to be via a metallic conductor of any type, or magnetically through the Ether. These conveyance methods are for later discussion. Terrestrial interference such as terrain, man made objects, Pinetropic and Coniferent interference and a host of other issues plague the linearities of the journey from the transmitter to the listener.

TIMING:

We have discussed the problematic existence of methods of amplification and the notion that the modulation is slightly detrimental to the action of the carrier wave sinusoid, even though as long as the reject load presents a good null. We have determined that these effects are minimal and have thus far exhibited no discernable effect on the recovered product. What then is the point? Timing. The presented modulation whether Analog or Digital only happens once in a time slice and is never repeated exactly again.

We could accept that the various methods of applied amplification apply various unthinkable negative effects on the desired amalgamated signal. These separate modes of amplification when applied in the accepted methods outlined but not limited to the above discussions, create an elevated effective radiated output power. All seems well. All is not well. There are frequency related group delays at work, as well as other problems.

With the distortion free critical timing of the Digital information being the key to a successful demodulation of the carrier wave (again regardless of metallic or Ether conveyance) any corruption or distortion of this Digital information will result in degraded performance.
As HD Radio does not have the advent of the adaptive equalization that HD Television does, the format suffers an additional inconvenient truth of degraded performance. Degraded performance from wave shape distortion, frame / sync timing, or linearity issues will damage the ability to convey and decode the desired message. Present technology can make allowances for some of these distortions when there is a substantiality of signal. What error correction there is embedded within the Digital word is able to fill in the problems when there is a sufficiency of signal and data.

In any method or format a sufficiency of signal is required, but in HD Radio this is exacerbated by the need for a level of sufficient signal so that any deficiencies are able to be overcome by the decoding chipset. Deficiencies of the data set are often overcome by the error correction available from high signal levels. Adaptive or forward error correction is only just so successful. If the signal level is too low, or the data is too damaged, the Mozart will not get through. Without this sufficiency, the cliff effect takes over right after the signal would begin to chirp embarrassingly. Damaged or defective data is the root of improperly time aligned combining.

THE CAUSE:
We have accepted quite a bit in regard to not rocking the boat of technology. We conform to methods of RF carrier wave combining and all other “good engineering practice” and still the coverage areas are small. After all, many manufacturers still believe that like grounding practices, it is still 1930. The answer lies in the timing. What is this timing?

Transmitter path number 1 which we will call George has a theoretical total average group delay of 360 degrees leaving the antenna. Transmitter path number 2 which we will call Georgette has a total average group delay of 810 degrees. This excess delay was developed as a result of the assembly of the combined systems, phasing cables, booster amplifiers and having a Georgette combiner feeder cable that was a bit short and the initial delay that was only 790 degrees in total. This 790 degrees created excessive reflected power from the combiner null so a phasing cable was needed to be extended because we can not shrink the delay of the second amplifier installation to achieve the desired R.F. sinusoid null. A quick look at the math shows us that Georgette has a total phase rotation in exceess of 2 complete revolutions (720 degrees) plus the required offset for combining of plus or minus 90 degrees. (assuming a hybrid) The person “skilled in the art” as the Patent Office would state, sees clearly that this is not a problem RF wise since convention has us add length until the null is achieved. The requisite combination of carrier wave energy will produce a minimal reflected power condition when rotated correctly, and the signals should appear normal. (as sinusoids go) The unfortunate point is that they only match the sinusoid when the modulation is applied. The location of the excess rotation in the path of either transmitter is important.

The fact that the rotation may exist in low power phase lengthening of BNC RG type cables, or in the higher power output piping is not the salient point to the result. The initial relative point is that without the proper rotation given the type of combiner, excessive dummy null will exist and cause additional problems down stream.

INSERT HIGHER MATH HERE
Negating the time alignment issue of the extra 90 degrees required for the RF combining of the two amplified streams, the issue is the extra rotation of additional degrees beyond the "A" or George transmitter. Assuming a carrier of 100mc and a delta time of .00001 milliseconds offset by 2 full rotations in delay. A delay of .00002 milliseconds will transpire.
In this time offset, the Digital data that exists in the time slice frame of the sinusoid of George will not be the same exact recoverable dataset as Georgette. No matter if the modulation is Analog or Digital, this shift in framing of the original dataset, split, amplified and re-combined will be offset sufficiently to cause distortion of the recovered Digital data. This distortion is cumulative to the distortion induced by the amplification and at some QOS point , the decoder will mute rather than warble like a chicken. This distortion will reduce the stability of the recovered data and will result in poor recovery performance of the data. Carriers that are excessively rotated in delay due to improper transmitter phasing techniques will corrupt the time slots even further to the reference transmitter and vice versa which will result is degraded performance.

THE EFFECT:
The shift in the alignment of the timing of the content delivery between George and Georgette creates problems in the Analog and Digital modes. While minor timing problems will shift forward in relativity to each other from tuning of the amplifiers (transmitters) which will most apparently result in noticeable elevated reflected power from the combining method, the toll is rippled backward down the frequency chain to the modulation. Shifts in the tuning of the transmitter will also have an effect on reflected power. This slight shift in the timing of the transmitters will cause a shift in the delivery of the message content. This message content of the Analog and Digital information have distinctly differing degradations. Shifts in the tuning of vacume based amplification also causes errors as seen in the shoulders and skirts of the mask energy. Though an active equalization system can mitigate some this set of issues, active equalization can not mitigate conflicting Analog and Digital word energy existing in the same time plane with differing content in a singular time plane.

This Digital degradation is apparent when viewed on a particular advanced Exciter that allows the user to monitor the quality of the recovered Digital word. The Analog degradation can be similarly tested for with the appropriate equipment. Demodulating the Digital data from carrier 23 by it self for example will yield recoverable bits of useful material. Simultaneously recovering Digital data from George time slot 23 and Georgette time slot 23 when Georgette is rotated out 2 to 5 extra rotations will meld totally different data sets and result in garbage and a fade to fatal Cliff Effect.

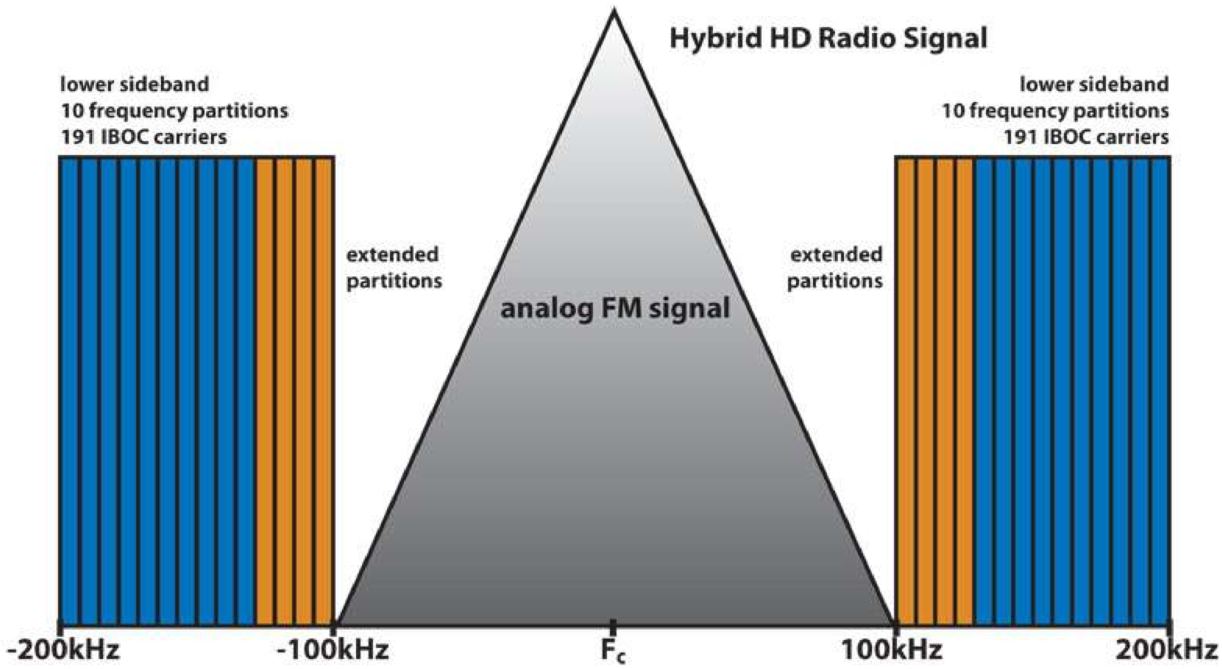
Shifting or drifting of the tuning of the carrier envelope due to changes in the amplifier hardware will cause variations in the recovered Analog and Digital audio in the form of spatial shift of perception from leading to lagging and vice versa when comparing the zero crossing time of the delay of the Analog signal to match the blend mode of the receiver. As long as the active equalization is operating, this problem is minimized as the Digital portion of the receiver mutes. In the test set up of the new combined system, a measurement of the delay time is made that primarily accounts for the time lag in the electronics of the audio processing. This time frame continues to grow as the complexity of the processor grows. Varying the tuning by shift or drift will cause a shift in this absolute recovered audio blend time. This shift or drift will also cause variable distortion to the recovered Analog signal. Though this is felt to be quite small, the shift is real.

The Digital side of the equation causes frame and timing errors to be introduced that low carrier wave signal levels promote. Without the brute force of an elevated receive signal, the chipset is more easily able to deal with the excess noise and jitter of the frame timing and un-matched time slot data issues caused by the extra .00002 milliseconds of linear delay. Though it is more able to hide these distortions by an abundance of data, the lower signal level areas, or the propagationally challenged areas resulting in severely degraded spectral delivery also promotes the Cliff Effect.

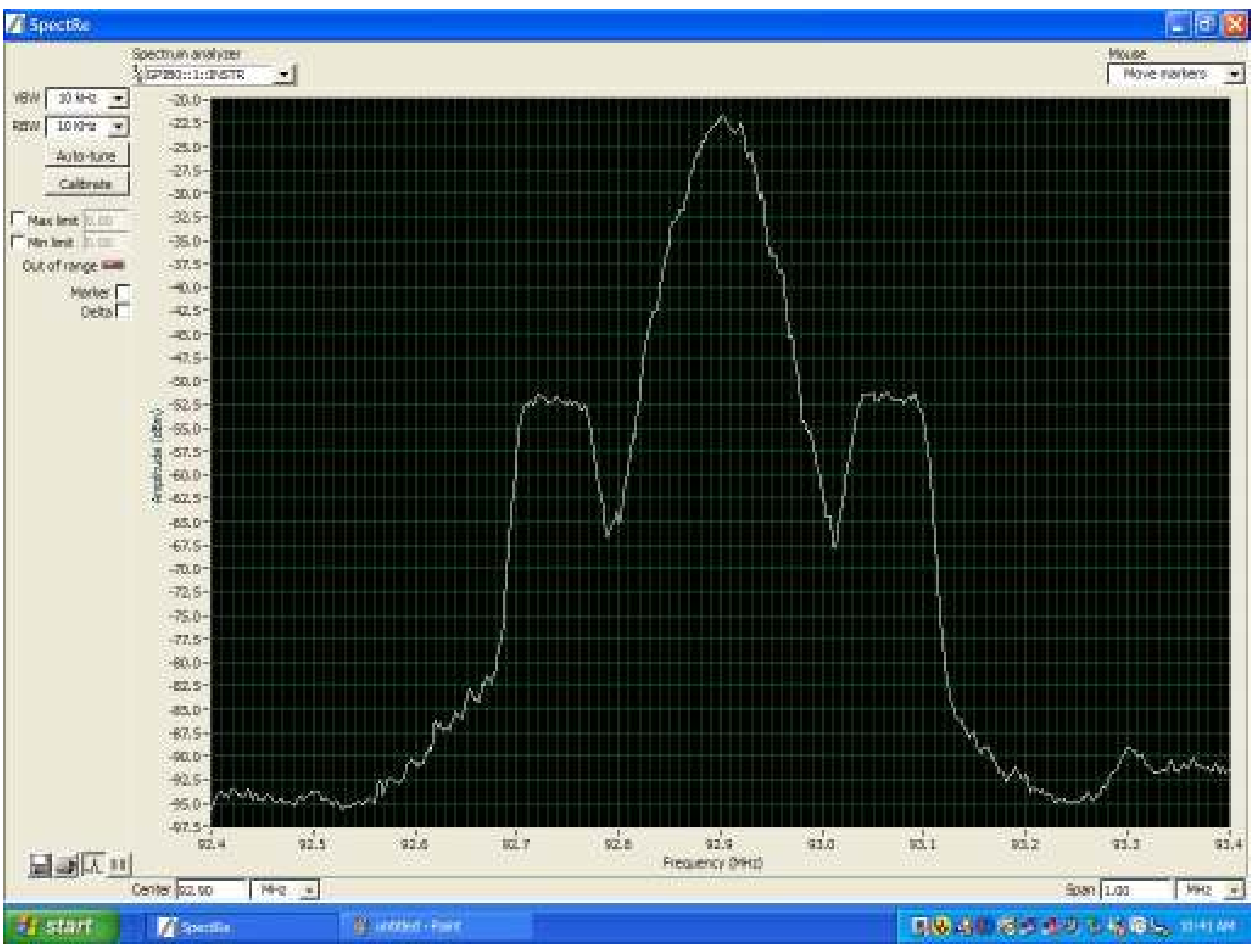
SYNOPSIS:
The purity of the transmitted hybrid signal is the key to successful message delivery. It is the intent of this paper to present this hypothesis from the point that an ingredient has been ignored in the promulgation of an effective radiated signal.

Though admittedly this hypothesis is not a glaring issue, the issue at hand is problematic in that the coverage and ability of this new format is not widely accepted, at least from a technical standpoint. (programming aside) It is the common practice to phase delay the Georgette transmitter. This is where the problem may lie. It must be clearly understood that group delay testing of the dual paths must be conducted so that the appropriate path may be delayed in order to create identical paths, as much as such objects can be considered identical. Eliminating additional hurdles in the promulgation of properly modulated signals can and will increase the reliability of the Mozart, if not the coverage. These issues also apply to Television transmission. It is not the "B" or Georgette transmitter that needs to be additionally delayed to make the null appear, it is more typically the "A" or George transmitter that needs to be slowed down to meet or match its counterpart in timing. Group delay testing of every stage of combined amplification needs to be matched against the over all delay of each amplified path to insure proper deliver of the Analog and Digital information for best recovered delivery.

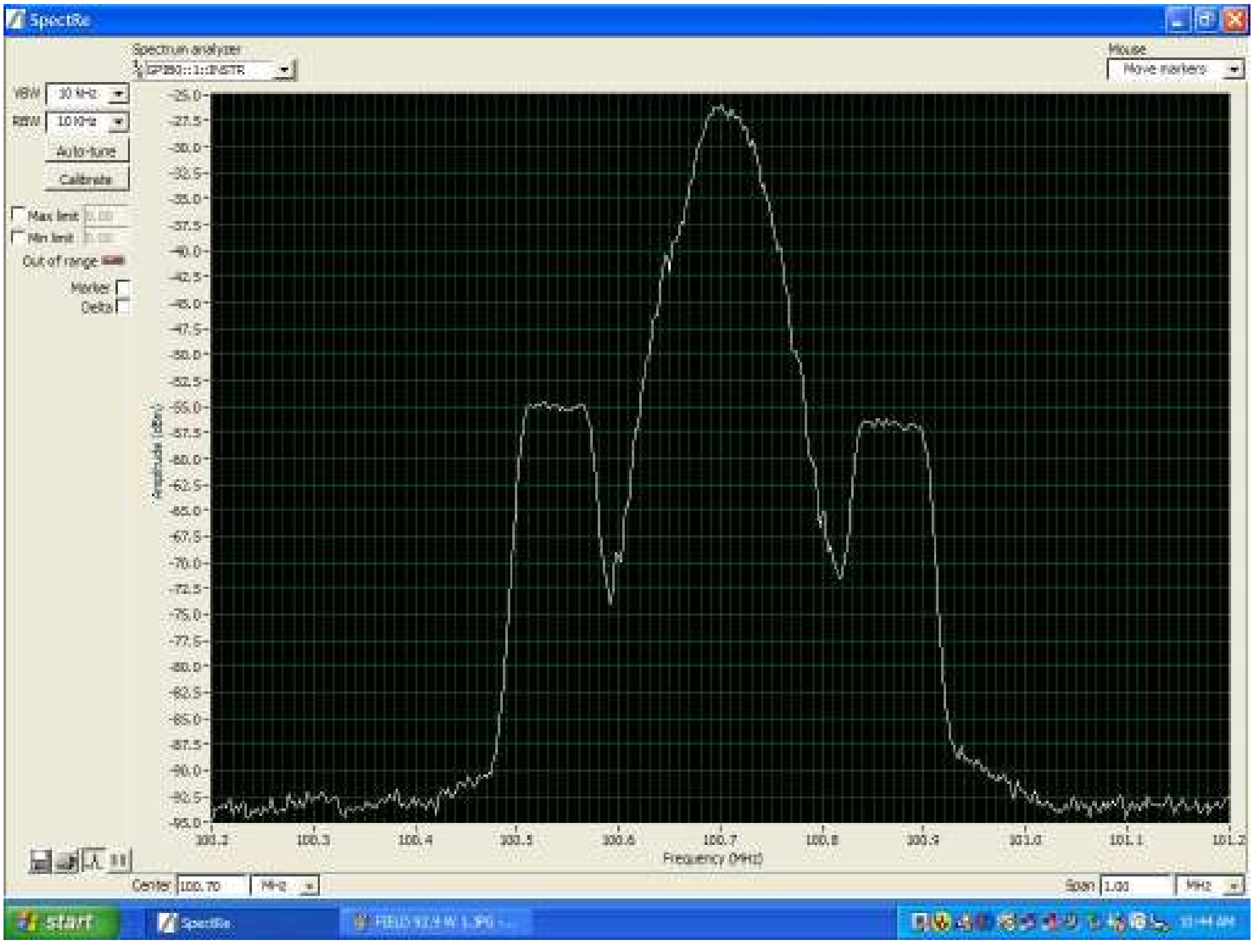
END OF ARTICLE



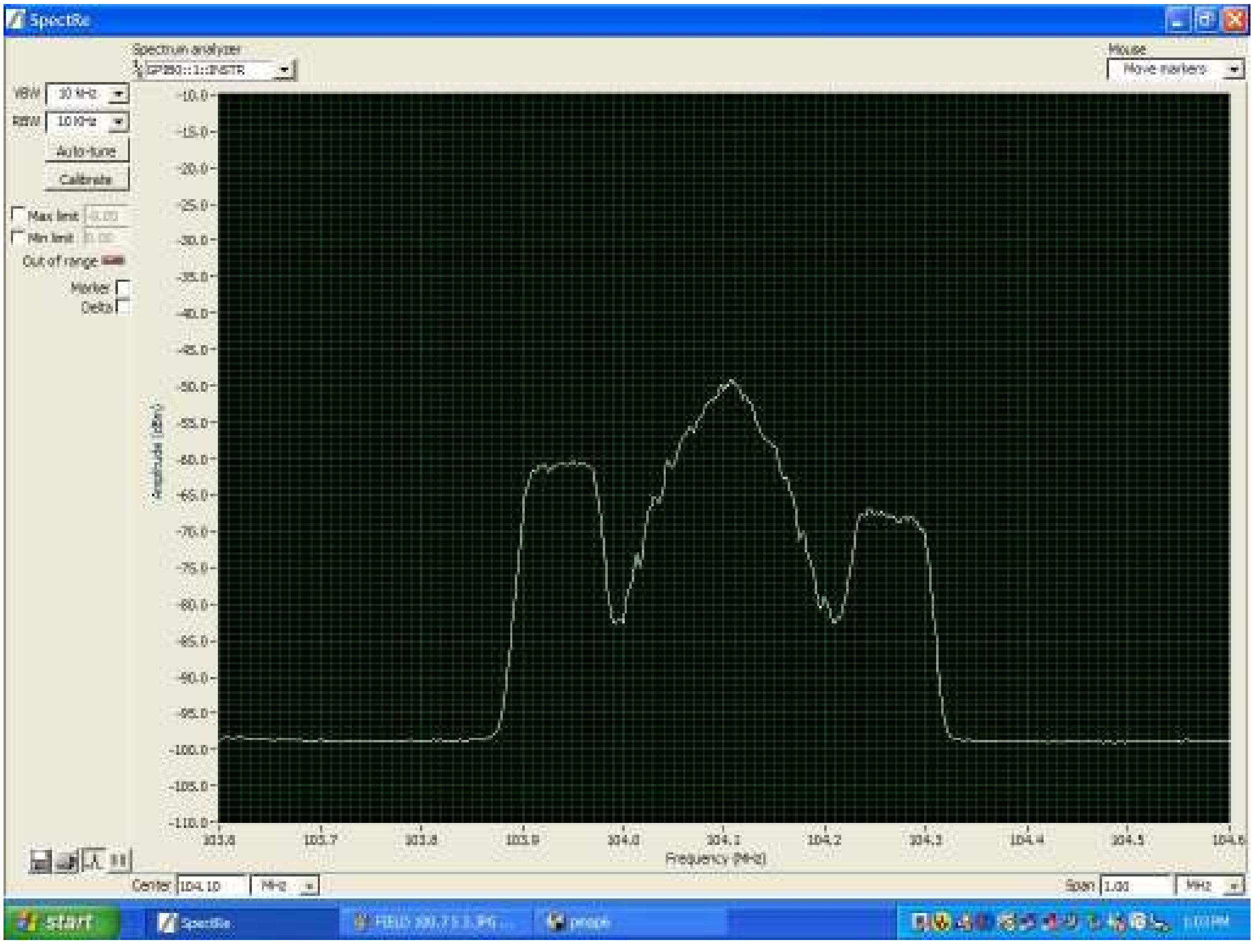
REPRESENTATION OF THE MULTIPLE HD SUB-CARRIERS THAT MUST TIME ALIGN IN ORDER TO BE PROPERLY DECODED.



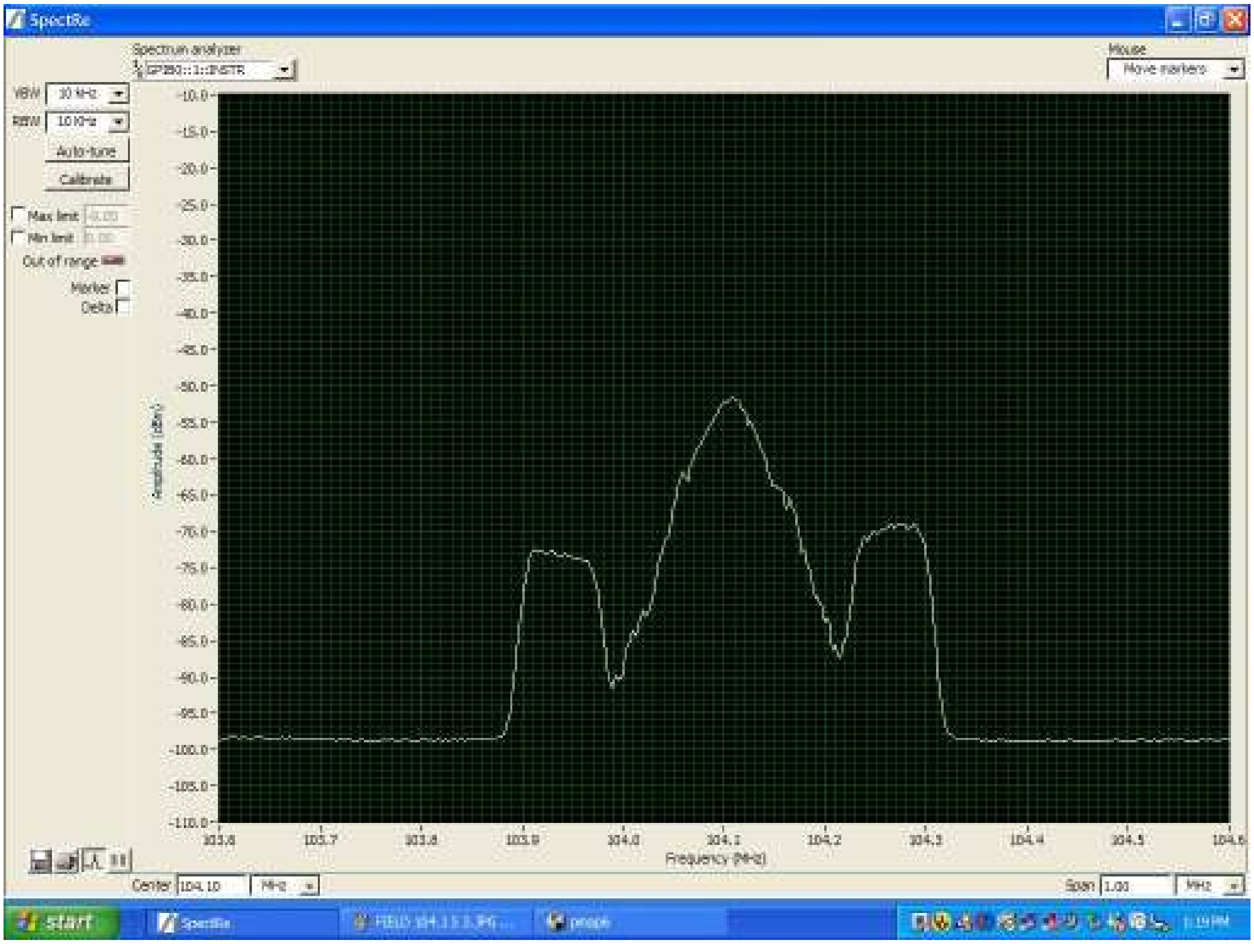
AN EXAMPLE OF A CAPTURED FM HD SPECTRAL PLOT UNDER NORMAL FIELD RECOVERY CONDITIONS



AN EXAMPLE OF A RECOVERED FM HD SPECTRAL PLOT EXPERIENCING NON-LINEAR PROPAGATIONAL DELAY IN THE UPPER SIDE BAND



AN EXAMPLE OF SEVERE PROPAGATION AL DELAY OF THE UPPER SIDEBAND OF THE FM HD SIGNAL. THIS IS NOT AN IMAGE OF ASYMMETRIC ENERGY APPLICATION AT THE TRANSMITTING SOURCE, THOUGH THIS IS A MORE RECENT ATTEMPT TO MAXIMIZE COVERAGE



AN EXAMPLE OF PROPAGATIONAL NON LINEAR SYMMETRY OF THE FM HD CARRIER SUB-SETS

END OF OBJECTS