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National Association of
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March 8, 1988

Dear Industry Engineer:

"Broadcasting and Democracy: The Winning Ticket," the theme of the 1988 convention, reflects the vital role that broadcasters play in the American election process. As engineers, we face the challenge of maintaining the technical quality of broadcasting, to ensure that broadcasting maintains the quality of democracy.

The papers contained within these proceedings present information on new ideas, technologies and methods that will augment your technical knowledge and skill. We encourage you to read and study these papers. Consider this study an investment in your future -- and the future of your industry.

On behalf of NAB's Science and Technology department staff, I am pleased to present these 1988 Engineering Conference Proceedings.

Best regards,

Michael C. Rau

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THE AM SPLATTER MONITOR

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INTRODUCTION

The AM Splatter Monitor is designed to evaluate a transmitter's level of AM interference while avoiding some of the limitations of existing measurement techniques[1]. The development of the AM Splatter Monitor is a result of the National Radio System Committee's (NRSC) desire to more effectively measure the performance of radio stations in evaluating the NRSC preemphasis standard (NRSC standard)[2]. One goal of this committee is the reduction of AM interference[3] (splatter), particularly second adjacent channel interference, using a high performance, 10 kHz low pass filter[4]. The AM Splatter Monitor is ideally suited to evaluate the effects of this filter on transmitted interference.

This paper discusses the nature and effects of splatter and describes the uses of the AM Splatter Monitor compared to other spectrum measurement techniques.

SPLATTER DEFINITION

Splatter is one of those intuitive but ill defined concepts with which every broadcast engineer is acquainted. To the author's knowledge, no technical reference dictionary defines the term. For the purposes of this paper, let splatter be defined as the undesired portion of a station's output spectrum caused by modulation. Using this definition, power supply hum sidebands and carrier harmonics along with co-channel and adjacent channel interference are not splatter. Second adjacent channel interference is splatter. Also, note that the exact definition depends upon the engineer's opinion about which parts of the transmitter output spectrum are desirable. This is natural because the engineer's expectations are partly determined by regulation and partly by existing technology both of which may change. Finally, splatter is defined for the station's output spectrum which includes both the transmitter's output spectrum and the far field spectrum.

THE SPLATTER PROBLEM

Splatter is a problem because it interferes with reception of other stations. Nearly everyone has experienced the steam-locomotive-like sound of second adjacent channel interference while trying to receive a weak AM radio signal, especially at night. This effect is due to splatter from another radio station. The presence of such splatter does not necessarily indicate a violation of FCC emission limitations rules[5] because the receiver's automatic gain control brings up the splatter along with the weak signal.

Several secondary effects of splatter are harmful to the AM broadcaster. The existence of splatter from thousands of radio stations raises the general noise level of the AM band and thereby reduces the quality of AM broadcast programming. Also, splatter is energy wasted because the splatter sidebands are never audible to the station's listeners. In fact, the signals which cause splatter may intermodulate in the transmitter to produce distortion components within the desired portion of the spectrum and, therefore, distortion in the received signal.

SPLATTER SOURCES

The primary cause of splatter is higher frequency audio components at the transmitter's modulator input[6]. These higher frequency audio signals are translated directly into splatter by the normal process of modulation. A typical source of these audio signals is an improperly filtered clipper in the audio processor. Fortunately, the better audio processors incorporate a low overshoot filter to eliminate these clipping products.

Other sources of splatter are overmodulation, improper use of the transmitter's protective clippers, distortion and noise in the modulator, incidental phase modulation (IPM), and improperly operated AM stereo. In the case of incidental phase modulation, the resulting phase modulation sideband pairs would not, if left undisturbed, affect receiver envelope detectors. However, these sidebands are disturbed by every tuned circuit all the way through to the detector, especially the asymmetrical skirts of the IF bandpass. So some of this sideband energy is converted to AM sidebands which are detected as distortion. This is why reduction of IPM by proper transmitter neutralization improves the sound of AM stations.

MEASUREMENT TECHNIQUES

The regulations governing emission limitations[7] do not specify the monitoring equipment to be used or the frequency of measurement but specify only that the broadcaster must not violate the internationally agreed upon spectrum limits. Thus, strictly speaking, the broadcaster must guarantee at all times that he is not violating these limits. In practice, however, the spectrum is checked only periodically, perhaps once a year, using a rented or borrowed spectrum analyzer or wave analyzer and the assumption is made that the spectrum is acceptable at all other times. Until now, this was the only practical recourse available to the broadcaster due to the high cost of the necessary measurement equipment and the requirement for competent technical people to operate the complex equipment.

Other equipment readily available, such as communication receivers and field strength meters, are not suitable for close-in spectrum measurements because they lack the necessary dynamic range and selectivity. Even a high quality spectrum analyzer has the limitation that as it sweeps through the measurement band, it looks at only a small segment of the spectrum at any given time. Thus, the spectrum analyzer would not record the existence of a burst of splatter at other segments of the measurement band[8].

THE AM SPLATTER MONITOR

The AM Splatter Monitor is a dedicated, specialty device primarily intended for full time measurement of the spectrum segments between 11 kHz and 100 kHz away from the carrier on both sides of the carrier. The AM Splatter Monitor measures splatter level and any spurious emissions which fall within this spectrum segment. The AM Splatter Monitor is an economical device designed to fit within the budget of an AM broadcast station. Figure 1 is a front panel view of the AM Splatter Monitor.

Because splatter level normally decreases with frequency away from the carrier, the AM Splatter Monitor measures the most important segment of spectrum associated with splatter. This same segment of spectrum is where the changes in splatter level occur. These changes are due to factors such as shifts in modulation level, changes in program material, audio processor adjustments, and tube aging. The AM Splatter Monitor has an alarm that may be set to detect such changes. The station can use this alarm through a remote control system to immediately signal the occurrence of a splatter problem.

The AM Splatter Monitor is normally installed in a rack at the transmitter site to continuously monitor the transmitter's output

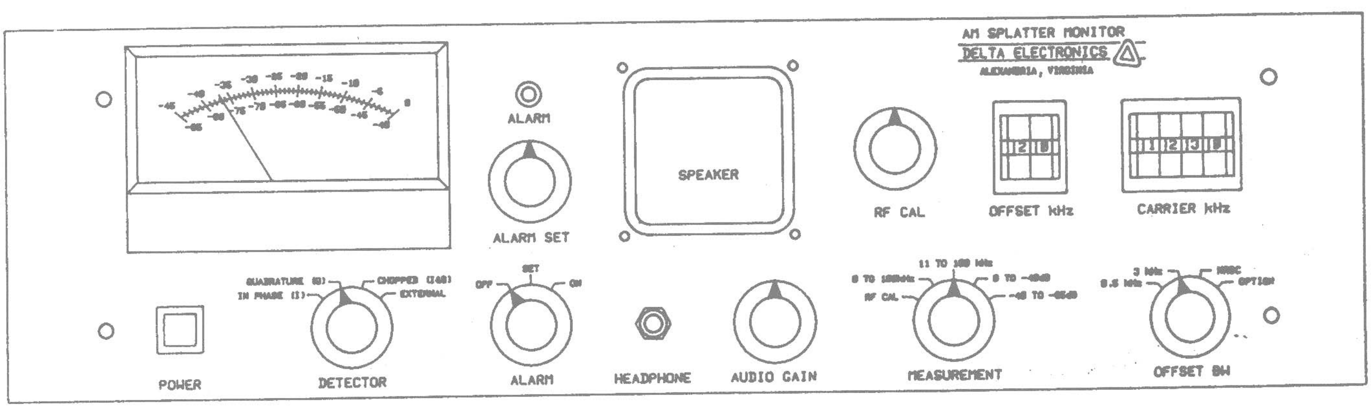

FIGURE 1

spectrum. Although the regulations regarding emission limitations require field measurement to assure compliance[9], the intervening elements between the transmitter's output and the far field are usually quite linear so continuous monitoring of transmitter's output is a reasonable indication of operational compliance. The AM Splatter Monitor is portable, and may be removed from the rack for field monitoring to assess compliance of the close-in spectrum (within 100 kHz) to emission limitations rules[10]. The unit may also be used for field monitoring in the strong signal areas of other AM stations to investigate interference complaints. For these purposes, the AM Splatter Monitor derives power from an automobile's cigarette lighter jack (+12V) and receives its RF input signal from an optional, active antenna.

Figure 2 is a simplified, functional block diagram of the AM Splatter Monitor. The reader is encouraged to refer to this figure while reading the following description.

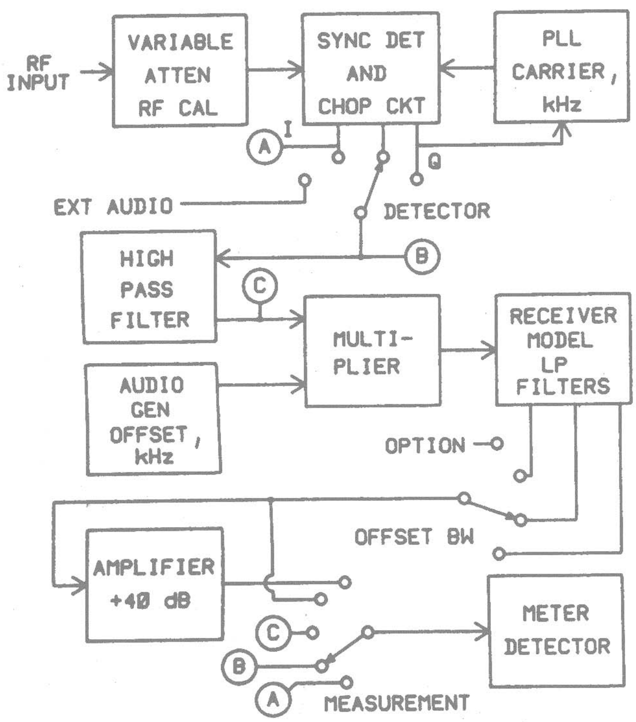

FIGURE 2

A 3 1/2 digit thumbwheel switch labeled CARRIER kHz adjusts the operating frequency of the AM Splatter Monitor from 450 kHz to 1700 kHz. Simple crystal and jumper changes allow operation at either 9 kHz or 10 kHz channel spacing. When tuned to 450 kHz, the AM Splatter Monitor can be connected to the 450 kHz IF output of a synthesized receiving, taking advantage of the AM Splatter Monitor's synchronous detectors either to evaluate receiver performance or for off the air monitoring. In monitoring applications, first evaluate the receiver using an amplitude modulated, signal generator and also evaluate the signal generator directly with the AM Splatter Monitor.

The AM Splatter Monitor uses high performance in-phase and quadrature synchronous detectors. The output of each synchronous detector is available on the rear panel. When used to measure splatter, the in-phase synchronous detector measures the splatter due to distortion and clipper products and the quadrature synchronous detector measures splatter due to incidental quadrature modulation which is related to incidental phase modulation. A measure of the overall splatter level requires a combination of the in-phase splatter and the quadrature splatter. A low frequency chopper circuit performs this function. The engineer uses the DETECTOR switch to select the in-phase detector, the quadrature detector, the chopped combination of these two detectors, or an external audio input depending upon his measurement needs. The external audio input is used to analyze the audio source material fed to the transmitter's modulator.

A five position switch labeled MEASUREMENT selects the function of the AM Splatter Monitor. In the first switch position, the AM Splatter Monitor measures the DC portion of the in-phase synchronous detector for calibration of the RF input level (carrier level). The second switch position selects measurement of all signals within 100 kHz of the carrier. The meter, when reading the in-phase detector or the chopper circuit, will typically read several dB down as it measures the desired modulation and splatter. The demodulated signal is audible from the front panel speaker or by use of headphones. In this switch position, the external synchronous detector outputs are used for receiver evaluation or off the air monitoring as mentioned above or are used with an FFT spectrum analyzer[11].

In the third switch position, a sharp high pass filter[12] is inserted so that the meter reads only that portion of the spectrum between 11 kHz and 100 kHz on either side of the carrier. This is a measure of the total splatter produced by the radio station and, unlike a swept spectrum analyzer, all spectrum components of interest are always available for measurement.

In the last two switch positions, the AM Splatter Monitor measures a selected spectrum segment of the total splatter signal in two ranges. The top meter range is elected by the fourth switch position and measures down to 45 dB below the calibration reference. The fifth and last switch position selects the bottom meter range which measures between 40 dB and 85 dB below the calibration reference. The segment of the spectrum selected is determined by a thumbwheel switch labeled OFFSET kHz and by a bandwidth switch labeled OFFSET BW. The OFFSET BW switch selects an equivalent receiver model and the OFFSET kHz thumbwheel determines how far that equivalent receiver is tuned away from the carrier on both sides of the carrier. For spectrum analyzer like applications, the OFFSET BW switch is set to the 0.5 kHz position yielding an RF bandwidth of 1 kHz which matches the step size of the OFFSET kHz thumbwheel. In the 3 kHz switch position, the AM Splatter Monitor responds like a typical narrow band radio. In the NRSC position, a wide band receiver is modeled with NRSC deemphasis. The switch position labeled OPTION allows selection of a customer determined receiver model contained on an optional plug in assembly.

A typical example of the use of the AM Splatter Monitor is monitoring the splatter produced on the second adjacent channels, 20 kHz away from, and on both sides of, the carrier. The OFFSET kHz switch is set to 20 for the required 20 kHz frequency offset. The OFFSET BW switch might be set to the 3 kHz position to measure the level of total splatter energy received by a typical narrow band receiver. According to the emission limitation rules[13], the maximum acceptable splatter level for this frequency is 25 dB below the carrier reference so the MEASUREMENT switch is set to the fourth position for measurements down to 45 dB below the carrier reference. The AM Splatter Monitor's meter must not read above the 25 mark on the top scale (-25 dBc).

The ballistics of the meter's detector circuit are set to match the integration factors of the human ear. Therefore, the meter reading for the example given above is equivalent to the interference level perceived by a listener. This is, of course, exactly the desired measurement if we assume that the purpose of the whole exercise is reduction of objectionable interference. The question may arise, however, of whether this measurement will agree with a measurement derived from some other measurement method. Will a spectrum analyzer, for instance, read the same as the AM Splatter Monitor? The answer is a qualified yes.

In the case of fixed sidebands due to test tone modulation, the peak detector of the spectrum analyzer responds the same as the quasi-peak detector of the AM Splatter Monitor. This is how the AM Splatter Monitor is calibrated. Modulation using the pulsed USASI noise source as recommended in the NRSC standard[14] yields the same readings provided that the spectrum analyzer is used either in the fixed frequency mode or with peak hold over a long time period. The same situation occurs with real modulation so that the qualification mentioned above is that the AM Splatter Monitor produces conservative readings, that is, if anything, higher readings than a sweep spectrum analyzer. Therefore, the AM Splatter Monitor is, in some ways, superior to a spectrum analyzer for this special application.

SUMMARY

Splatter is unwanted spectrum components due to modulation which interfere with other stations and cause distortion of the desired signal. The AM Splatter Monitor measures the level of splatter and can be used to identify and correct the sources of splatter. The AM Splatter Monitor is primarily intended for continuous monitoring of the transmitter output to indicate operational compliance to the regulations governing spectrum limitations[15]. It is also useful for field measurements in strong signal areas. The AM Splatter Monitor's alarm can be used to remotely alert the occurrence of splatter problems. The high performance, synchronous detectors in the AM Splatter Monitor make this unit useful for a variety of other applications.

REFERENCES

[1]Harrison J. Klein, P.E., Modulation, Overmodulation, and Occupied Bandwidth: Recommendations for the AM Broadcast Industry, (NAB September 1986) p. 22

[2]National Radio Systems Committee (a joint National Association of Broadcasters and Electronic Industries Association group), Interim Voluntary National Standard, (January 1987)

[3]op. cit. NRSC p. 1

[4]Ibid p. 7

[5]Federal Communications Commission, Rules and Regulations, Part 73, #73.44

[6]op. cit. Klein p. 23

[7]op. cit. FCC

[8]op. cit. Klein p. 22

[9]op. cit. FCC
[10]Ibid

[11]op. cit. Klein p. 23

[12]Courtesy of Bob Orban, Orban Associates, Inc., 645 Bryant Street, San Francisco, CA 94107

[13]op. cit. FCC

[14]op. cit. NRSC p. 9

[15]op. cit. FCC

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A NEW LOW PROFILE ANTI-SKYWAVE ANTENNA FOR AM BROADCASTING

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ABSTRACT

A new technique for controlling the elevation plane pattern of broadcast antennas is presented. Practical results, measurements and theoretical predictions are evaluated and discussed. It is concluded that the new Corum structure is a viable candidate for solving skywave problems and for providing low profile radiators where traditional antennas are impractical.

Introduction

A novel technique for the control of the elevation plane pattern of broadcast antennas has been developed at Pinzone Communications Products' Newbury, Ohio laboratory and the antenna test range at its rural Windsor, Ohio engineering experimental station. This remarkable new technology makes possible the practical implementation of anti-fade and anti-skywave antennas.

Nighttime skywave interference has continued to be a major plague for the AM broadcast service since the early days of radio. For most broadcasters, skywave radiation presents two problems. First, it represents wasted radiated power. Secondly, because of the legally protected contours of existing stations, high angle radiation severely limits a broadcast station's market place, or primary coverage area. From a pragmatic point of view, if the interferrence-causing high angle radiation could be significantly reduced, in many cases, the transmitter power and ground wave coverage could be dramatically increased with no additional interference to other stations. The potential market place economic impact is obvious.

High angle radiation is also a plague to clear channel broadcast stations. The groundwave daylight service area, for a clear channel station, may exist out to a considerable range. However, the nighttime skywave signal can be greater than the groundwave signal well within the daytime coverage area. When the groundwave and skywave signals are of the same magnitude, they can phase out one another, resulting in serious fading and irritating audio distortion in the detected signal at the consumer's receiver. The outer edge of the primary service area, caused by this self-interferrence phenomenon, is called the "fading wall". Its physical elimination is only possible by the reduction of high angle radiation.

Historical Perspective

The history of the anti-skywave problem makes for fascinating reading. Stuart Ballantine, in the second of his two historic papers from Harvard in the 1920's, according to Laport, ". . . disclosed a hitherto unknown fact: there was an optimum height for a vertical radiator for obtaining maximum groundwave field strength."[1]

Laport continues, "Further study of the optimum height antenna disclosed eventually that the conditions of maximum groundwave and best antifading characteristics were not obtained with the same height. . . .The optimum choice for antifading over land was experimentally established at about 190 degrees."[1] The 225 degree tower gives the maximum groundwave but its high angle lobe produces a non-negligible fading wall.

Laport, in his fascinating 1952 publication, observes that, "By 1934, the modern broadcast radiator had evolved to its present state."[1]

Summarizing the state of affairs in the early 1950's Laport concludes, "Diligent research and experiments have been conducted for other possible broadcast principles that might equal or surpass those disclosed by Ballantine."[1] As we know today, the results (though often significant) have been of marginal utility.

Practical Requirements

Over the past several years a renewed interest in anti-skywave antennas has been exhibited by broadcasters, the NAB and consulting engineers. The noteworthy papers publishing the separate approaches of Biby and Prestholdt indicate the creative effort put forth to arrive at acceptable alternatives to expensive radiators of heroic proportions.[2,3]

Perhaps the clearest verbalization of the necessary technical requirements which challenge the creation of any realistic Anti-Skywave Antenna was put forth by Richard Biby in his 1986 NAB Engineering Conference technical paper:

> "In order to be really economically viable, an 'Anti-Skywave' antenna design concept must be able to take the typical 90 degree vertical tower, with a conventional buried copper wire ground system, make minimal changes thereto, and end up with decreased nighttime interference and improved groundwave signal strength. All the while, the system should remain non-directive, but still offer the possibility of being made directive in the horizontal plane if such were needed."[2]

To this we would also add, because of the Sommerfeld attenuation function, the structure must produce only a vertically polarized groundwave. What is needed is some way to increase the vertical current moment of the radiating system (the integral of $i \bullet dl$).

This has been done, and Pinzone Communications Products, Inc. has just such a solution available.

The patented Corum Antenna provides a splendid candidate to simultaneously surmount all of the above engineering requirements.

It can be used to retrofit existing towers, at ground level, and produce an enhanced elevation plane directivity previously unavailable to design engineers.

Elementary Considerations

Normal mode helices have been of interest since Pocklington's famous 1897 paper. One particularly intriguing idea is to take a self resonant normal mode helix, pull it around into a closed multiply connected region and let the resulting structure, which has been called a "Corum Element", combine the tuning and matching networks with the radiating structure itself.[4,5] The radiation resistance is now in series with the coil inductance, and this combination is shunted by the helix turn-to-turn capacitance. The impedance transforming nature of this lumped circuit equivalent is well known, and it also has the advantage of transforming a relatively small feedpoint current into a stepped up current passing through the radiation resistance.

There exist a variety of techniques available to predict the behavior of simple antennas. Because of the geometrical complexity of our structure, traditional moment methods are not only cumbersome, but require inordinate computer time and yield little insight into the physics of the antenna. We have found the Kron/Gobau Diakoptic technique much more promising. We can attest to the oft heard complaint that, "The method of moments is little more than a numerical experiment. It generates no analytical formula or expression by which to gauge how the result might change with a change in configuration . . . insight can only be gained by running the experiment again and again." Consequently, we favor an analytical model for the physical insight which it provides.

The field theory analysis of the basic Corum element is fairly straightforward. Since the structure is a slow wave self resonant helix, it is reasonable to assume a superposed sinusoidal distribution of electric and magnetic current, where the electric current is given by

$$(1) \quad J(r') = I_o \mathrm{Sin}(n\phi') \, \delta(\mathrm{Cos}\,\theta') \, \frac{\delta(r'-a)}{a} \, \hat{\phi}'$$

the coordinates having their usual meanings (see figure 1), and the magnetic current is found from

$$(2) \qquad I_m = \mu\omega(\pi b^2/s) \; I_o \, \mathrm{Cos}(n\phi')$$

where a is the major radius of the torus, b is the helix radius (the minor radius of the torus) and s is the turn-to-turn spacing. In these expressions, n is a mode number for the current distribution on the structure. The radiated fields are determined in Reference 4 as:

$$(3a) \quad E^e_\phi = -\frac{\beta_g a Z_o I_o}{2r} \cos n\phi \;\; J'_n(\beta_g a \sin\theta) \, e^{j(n\pi/2)}$$

$$(3b) \quad E^e_\theta = \frac{n\beta_g a Z_o I_o}{2r} \sin n\phi \;\; \frac{J_n(\beta_g a \sin\theta)}{\beta_g a \tan\theta} \, e^{j(n\pi/2)}$$