Self-interference and Loss of SNR within Overlapped Coverage Areas of ATSC On-channel Distributed Transmitters

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Abstract*—This paper provides a method for the analysis of self-interference by on-channel, ATSC modulation, distributed transmitters. The analysis demonstrates how, in the areas of overlapped coverage, the composite Signal to Noise ratio (SNR) of distributed transmission drops below the SNR of a desired signal from single transmitter. The overlapped areas prone to SNR degradation are those where the signals from any two transmitters are within 30dB of each other. In these areas, the combined SNR of individual transmitters, when added to processed multipath, result in lower SNR relative to that of a single transmitter. This indicates that the expectation of improved service everywhere may not be realized by simply providing higher field strength over some area. In fact, self-interference and loss of SNR margin are inevitable within a significant portion of the overlapped signal areas. The analysis of composite SNR demonstrates that on-channel Distributed Transmission Systems (DTS), also known as Single-frequency Network (SFN), would primarily be suitable in terrain-shielded areas where overlapped coverage areas would be kept at a minimum. In urban and suburban environments where extensive overlap of signals from multiple transmitters would be unavoidable, self-interference would degrade reception for many consumers. Consumers subject to self-interference may be able to overcome some of the SNR degradation by using steerable directional antennas. Finally, it is shown that the expectation by the Federal Communications Commission (FCC) of minimal self-interference is unfounded and that the FCC's criterion for co-channel interference is inadequate for evaluating self-interference of multiple, on-channel, synchronized transmitters.

I. INTRODUCTION

The concept of an on-channel network Analog Television (ATV) transmitter with overlapping coverage areas has been rendered useless by the inability to synchronize transmitters and the limited capability of ATV receivers to operate well in a multipath environment. The only such network known to exist is in Puerto Rico where it was deployed to take advantage of terrain shielding to minimize the inevitable self-interference that would result without it. In the rest of United States, off-channel translators are in use by broadcast ATV to improve coverage and service.

The ability to synchronize multiple on-channel Digital Television (DTV) transmitters is a fundamental requirement of digital television's Single Frequency Networks (SFN), also known as DTS.

Transmitter synchronization is a necessary but insufficient condition for a successful operation of such networks. In addition to being able to perform precise synchronization of all transmitters, reception subject to dynamic multipath and minimization of self-interference among multiple transmitters are also essential to a successful implementation of DTS.

Major proponents of DTS in the U.S.A are the Advanced Television System Committee (ATSC) and the Federal Communications Commission (FCC). The ATSC is responsible for the development of DTV standards, and in that capacity it has issued a "recommended practice" for the design of DTS [1]. The FCC is the agency charged with regulating the use of radio frequencies in the U.S.A. In November 2008, the FCC issued a Report and Order [2] authorizing the deployment of DTS subject to certain technical rules.

Among others, the anticipated benefit of DTS, as outlined by the FCC and ATSC, is improved service to mobile and home viewers attainable through "more uniform field strength" and through "filling-in" of gaps in coverage. It should be noted that well-designed broadcast antennas for television already provided relatively uniform field strength, typically 95±5dBu for full-power stations, within 15km of the antenna.

The FCC and ATSC documents fall short with regard to self-interference and loss of SNR analysis. A thorough analysis of self-interference in the areas of where multiple signals overlap is critical to a successful DTS design because of the potential of reception degradation to many viewers while “cherry-picking” improved reception to some viewers.

II. ATSC ADAPTIVE EQUALIZERS

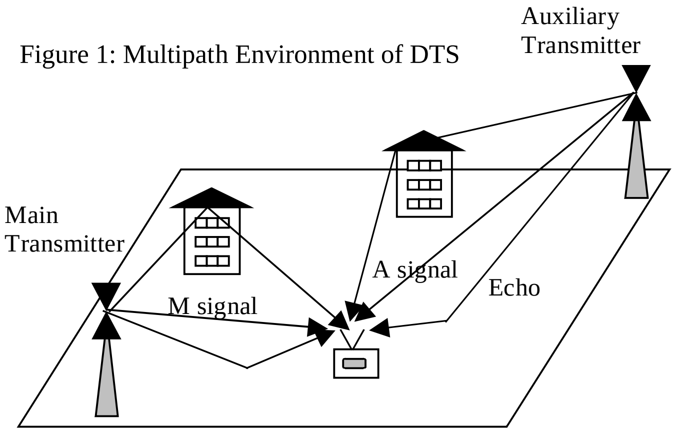
All DTV receivers require adaptive equalization to maximize the SNR margin above threshold SNR, also known as cliff-edge. The complexity and sophistication required of the adaptive equalizer depend on the modulation format. The multiple-carriers modulation format of the DVB-T standard is known as COFDM. COFDM is ideally suited for DTS applications because each basic symbol consists of the transmitted symbol followed by an adjustable guard interval. Multipath arriving within the guard interval time window is useful signal power in the SNR equation [3]. Thus COFDM receivers are equipped with a simple adaptive equalizer designed to provide flat response over the channel. The choice of guard interval and the number of modulated carriers, rather than the complexity of the adaptive equalizer, control the performance of COFDM in dynamic multipath environments.

In contrast, the modulation format of the ATSC standard, known as 8-VSB, does not have a guard interval. Consequently, the adaptive equalizer is a critical link in the chain of synchronization, equalization and demodulation of the desired DTV signal selected in an environment of undesired noise generated by multiple signals and echoes.

The dynamic multipath environment characteristic of the simplest DTS is depicted in Figure 1. At a minimum there is at least one echo or reflection associated with each transmitted signal. Typically there would be several echoes arriving at the receiver at different times. If the receiver is indoors, there would be additional echoes from walls, and the selection of the dominant and dynamic signal may be problematic. In general, echoes are not static as their magnitude and time of arrival depend on people and automobiles moving nearby, airplane flutter and or weather conditions. The ideal equalizer for ATSC receivers would coherently combine all signals and echoes resulting in an increase in the total useful power and thus in the composite SNR. Such an adaptive equalizer would function in lieu of the guard interval inherent in COFDM modulation. Unfortunately, that algorithm has failed the test of dynamic multipath [4] and is not known to have been implemented in the latest generations of consumer-grade receivers.

In reality, the adaptive equalizers used in consumer-grade ATSC receivers attempt to select the strongest signal as the desired signal and attenuate as many of the other signals and echoes. The signals and echoes outside the range and capability of the equalizer are not attenuated. For example, some unequalized echoes may be too strong and too dynamic. All attenuated and unequalized echoes and signals become added noise and thus lower the composite SNR, sometimes below the DTS threshold SNR. The DTS threshold SNR and the loss of SNR are the subjects of Section III.

Figure 1: Multipath Environment of DTS



The extent and dynamics of multipath environments mandates design tradeoffs for ATSC adaptive equalizers. For example, processing time, number of taps, added noise, time window to accommodate pre and post echoes (relative to the selected desired signal) and response to strong dynamic echoes have limited range in time-domain and frequency-domain equalizers. By necessity then, upper and lower performance levels of equalization must be prescribed to facilitate system analysis.

Three equalizer models will address the range of performance levels pertinent to the SNR analysis of DTS systems. The three ATSC models are:

Perfect Equalizer: A perfect equalizer selects the strongest signal as the desired signal and completely eliminates all other signals and echoes. There is no added noise due to processing and the processing is much faster than any dynamic changes in the propagation paths. Obviously this is model cannot be implemented.

Excellent Equalizer: An excellent equalizer has a sufficient time-window to accommodate all pre and post DTS added echoes and it attenuates all undesired static and dynamic undesired DTS signals and echoes by at least 30dB.

Poor Equalizer: A poor equalizer has a limited time window. It fails to process complex or dynamic undesired DTS signals. Such a performance is tantamount to no equalization in the real world of consumer reception even with outdoor antennas.

The definition *Excellent* and *Poor* are meant to provide the performance boundaries of equalizers in consumer-products. The actual performance of an individual equalizer is expected to fall inside the *Excellent* and *Poor* range.

III. SNR ANALYSIS

The SNR analysis is a two-step process. First the threshold SNR required by each transmitter for reliable DTS operation is established. Second, the degradation of the combined SNR as a function of the relative signal levels is derived. The result is an SNR template as a function of the ratio of the desired and undesired signal level in the presence of moderate echoes[a] generated by activating DTS. This template would then be applied to examples of overlapped coverage areas. For simplicity, only two transmitters are analyzed in the azimuth plane (Section IV) and in the elevation plane (Section V). But the method developed here could be applied repeatedly to multiple transmitters. Although the theoretical threshold SNR for 8-VSB modulation is 15dB, the actual threshold for a single transmitter is closer to 18dB without multipath. But, as shown in Table I[b],

Table I: SNR Budget for a Single Transmitter-to-Receiver Link
Excluding man-made noise, Rx-generated intermodulation products and interference

Parameter	SNR Budget (dB)	Loss (dB)	SNR Loss Notes
Transmitter's SNR of the Desired Signal	27-33	4.60-10.60	SNR Margin post filters switches and channel multiplexer.
Threshold SNR Under Fading	**22.40**	**2.40**	**Local Short-term Signal Fade Margin for 99% availability. Measured at the CRC. "Planning Factors for Fixed and Portable DTTV Reception." IEEE BTS Transactions, Sept 2004**
Equalizer Processing Noise Margin	20.00	2.30	Field tests show a minimum SNR of 20dB without fading margin required at the receiver prior to DTS being turned On. Also cited in ATSC-A/111.
Receiver Antenna Impedance Mismatch	17.70	1.70	Based on impedance mismatch between the antenna and the tuner. Measured at the CRC. "Planning Factors for Fixed and Portable DTTV Reception." IEEE BTS Transactions, Sept 2004
Transmitter Antenna Impedance Mismatch	16.00	.80	Calculated and measured. "Planning Factors for Fixed and Portable DTTV Reception." IEEE BTS Transactions, Sept 2004. Not part of the Tx equalization loop. The loss due to the antenna's transfer function, which varies with direction, is excluded.
Threshold SNR of Actual Receivers	15.20	.20	Based on laboratory tests at the FCC and ATTC. Limited by thermal noise. Receiver nonlinear distortion excluded. Does not apply to edges of dynamic range in severely degraded propagation channels.
Theoretical Threshold SNR of 8-VSB Modulation	15.00		Perfect link.

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[a] The ATSC definition of echo level between –10dB and –6dB as "moderate" is adopted here.

[b] Table I should be red from the bottom upward.

the threshold SNR link budget rises to 22.4 dB for DTS operating in a dynamic multipath environment.

The ATSC-recommended transmitter SNR is 27dB [5]. Modern transmitters may have higher SNR with 30dB being average. There are two questions to be answered in the following analysis. First, how does the composite SNR of multiple transmitters drops in each location throughout the coverage area from the initial 30dB as the number of transmitters and associated multipath increase? Second, at which location does the composite SNR drop below threshold? According to Table I there would be a 4.6-10.6dB margin above cliff-edge for new multipath, undesired signals, transmitters' noise, interference and man-made noise.

The algorithm for the loss of SNR is given as a ratio in Equation (1) and converted to dB for computational convenience in Equation (2). Additionally, all echoes are assumed generated by reflections of the undesired signals and, in Equation (2), are assumed equal in power. In Equation (2) the choice of one transmitter as Main (M) and the other as Auxiliary (A) is arbitrary and

Tx_M = SNR of the Main transmitter and M/ Tx_M is its inherent noise level.

Tx_A = SNR of the Auxiliary transmitter and A/ Tx_A is its inherent noise level.

$|\Gamma|$ = Relative amplitude of one echo

α = Equalizer attenuation of undesired signals and echoes

In Equation (2) The quantities A/M, Tx_M, Tx_A, α, and $(1+n|\Gamma|^2)$ are in dB.

Note that only the transmitters' inherent noise, new echoes and the undesired signal are factored into Equation (2). For simplicity, other noise sources such as man-made and nonlinear distortion generated at the receiver are omitted. Other link parameters are part of the threshold SNR shown in Table I. Figure 2 shows the graphic representation of Equation (2) without echoes. In the latter case, the three sources of SNR degradation are the inherent noise of each transmitter and the undesired transmitter, the weaker of the Main and Auxiliary transmitters.

$$SNR = \frac{M}{M/Tx_M + A/Tx_A + A\alpha\left(1+\sum_{i=1}^{n}|\Gamma|^2\right)} \quad Main > Aux \qquad (1a)$$

$$SNR = \frac{A}{A/Tx_A + M/Tx_M + M\alpha\left(1+\sum_{i=1}^{n}|\Gamma|^2\right)} \quad Aux > Main \qquad (1b)$$

$Main > Aux$

$$SNR(dB) =$$

$$-10Log\left[10^{-\frac{Tx_M}{10}} + 10^{-\frac{\left(Tx_A - \frac{A}{M}\right)}{10}} + 10^{\frac{\left(\frac{A}{M}+(1+n|\Gamma|^2)+\alpha\right)}{10}}\right] \qquad (2a)$$

$Aux > Main$

$$SNR(dB) =$$

$$-10Log\left[10^{-\frac{Tx_A}{10}} + 10^{-\frac{\left(Tx_M + \frac{A}{M}\right)}{10}} + 10^{+\frac{\left(-\frac{A}{M}+(1+n|\Gamma|^2)+\alpha\right)}{10}}\right] \qquad (2b)$$

There are two sets of curves in Figure 2. One is for an adaptive equalizer defined earlier as "*excellent*," albeit not likely to be found in consumer-grade ATSC sets, and one set of curves for an adaptive equalizer defined earlier as "*poor*," which represents essentially no equalization. The actual performance of any DTV set in a DTS environment would then fall between the two curves.

The loss of SNR is worst in the region where

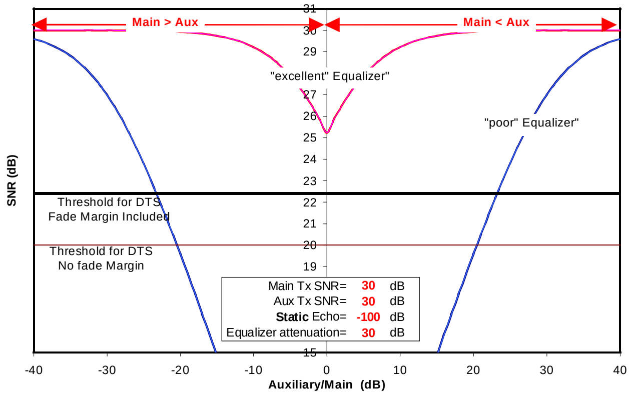

Figure 2: Composite SNR Inside Auxiliary/Main Overlapped Signal Areas Without Echoes

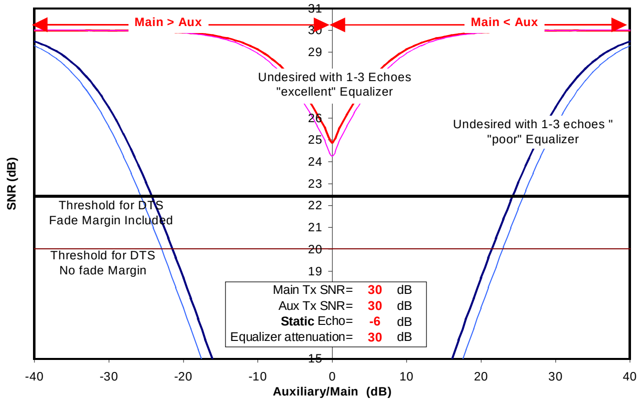

Figure 3: Composite SNR Inside Auxiliary/Main Overlapped Signal Areas "moderate" echo per A/111

the powers of two transmitters are within few dBs of each other. In that region, even with the best equalizer, the composite SNR drops to near threshold. With failed equalization, reliable reception would not be possible unless the dominant signal is at least 25dB higher than any other signal.

Figure 3 is the graphic representation of Equation (2) with 1-3 equal echoes. Note that even as the desired signal is at least 30dB stronger than the undesired, the SNR margin is only 3dB above threshold when dynamic echoes with poor equalizer are present. This 3dB margin would shrink further if the unavoidable FMI (FM interference) and man-made noise were added. Whatever SNR margin there is, it decreases very fast as the signal ratio Desired/Undesired approaches equality (0dB).

In general, Figures 2 and 3 demonstrate that for DTS to succeed, the dominant signal inside the overlapped coverage areas must be much more powerful that all other signals, perhaps by as much as 30dB[c]. That would be very difficult to accomplish without resorting to "cherry picking" the favored areas of coverage and accepting self-interference in the area surrounding the favored area.

IV. SELF-INTERFERENCE EXAMPLE I: LOSS OF SNR IN THE AZIMUTH PLANE

In this example, shown in Figure 4, the Main transmitter was designed to cover 270^0 of azimuth and the Auxiliary transmitter was designed to cover the remaining 90^0 of azimuth toward SE. The two antennas are at the same height and are synchronized but physically separated. The peak Effective Radiated Power (ERP) from the Main antenna is equal to that of the Auxiliary antenna[d].

As a practical matter, the two patterns overlap regardless of the physical separation between the antennas and in this case the overlap was kept to a minimum in order to maximize service and coverage over 360^0. Even so, in the directions of 70^0 and 165^0, the central directions of the overlapped coverage, the ratio Aux/Main power is 0dB. As shown in Figures 2 and 3, in those directions the self-interference would be strongest and the loss of SNR would be highest.

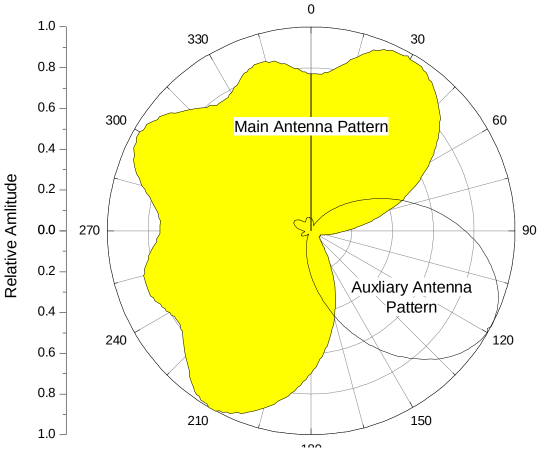

Figure 4: Individual Azimuth Patterns of the Main and Auxiliary transmitters
The antennas are at equal height and are geographically seperated

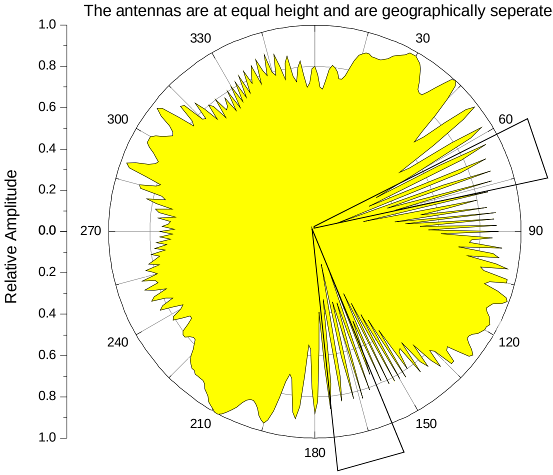

Figure 5: Composite Carrier Azimuth Pattern
Triangles show arbitrary arcs of low signal and poor bandpass response

Traditionally, the calculated composite pattern of multiple antennas is based on continuous carrier and does not include any corrections that might be implemented at the receiver. That composite azimuth pattern of the two antennas is shown in Figure 5. Because the two antennas are sufficiently separated, the differential path to the receiver varies fast with the azimuth and the vectorial sum of the individual field strengths inside the overlapped patterns varies widely as the individual signals combine in and out of phase as a function of direction. Where the composite signal has deep nulls, the two arcs where self-interference appears, each about 15^0, were designated as areas of "spotty or no reception" and subsequent field tests have shown that inside those arcs DTV reception is indeed problematic.

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[c] Also based on the loss of SNR examples in Sections IV and V.

[d] With minor variations this design mirrors the design of the 6-channels master DTV antenna operating on top of the Empire State Building in New York City since July 2008.

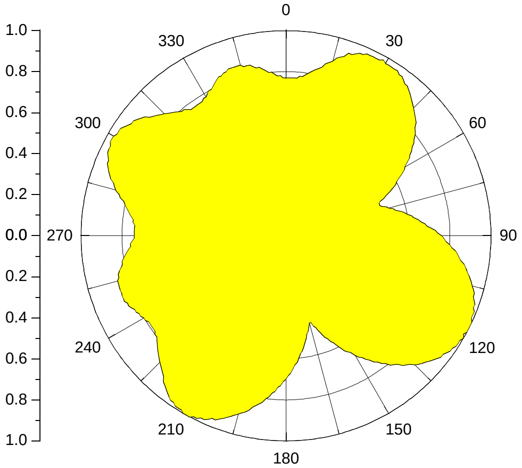


Figure 6: Unrealizable Equalizer Correction
Transmitters' SNR=∞ with flat passband response and no echoes

The designation of the two 15^0 arcs as areas of “spotty or no reception” was intuitive. It was based the expected rate of phase variation (group delay) and the loss of field strength. The concurrent loss of SNR calculation was not an option at the time the antenna system was designed.

With the SNR algorithm developed in Section III and assuming the transmitter parameters of Figure 2, it is now possible to determine the actual loss of SNR at the receiver due to self-interference inside the overlapped patterns.

Figure 6 shows what the received composite pattern would be without transmitter noise and with the *perfect* equalizer defined in Section III. The received pattern is essentially omnidirectional without loss of SNR regardless of the physical separation between the two transmitters. If such a adaptive equalizer performance could be realized, it would be ideal not only for consumers but also for broadcasters who lack tower space, and for antenna designers.

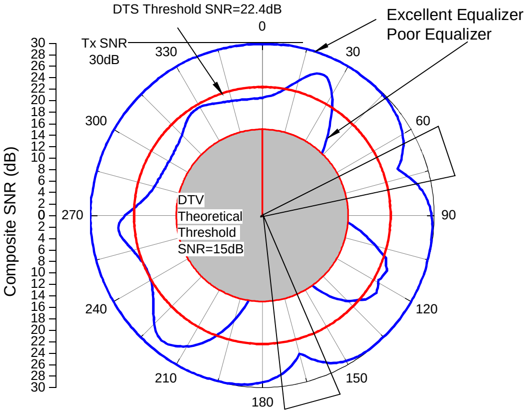


Figure 7: Composite SNR with (a) Excellent Equalizer and (b) Poor Equalizer
Based on DTS shown in Figure 4

With real adaptive equalizers, realistic transmitter noise and added moderate single echo of –6dB, the composite SNR of such a DTS system is shown in Figure 7. The added antenna that filled the gap toward SE generated self-interference and loss of SNR over significant arcs clockwise and counterclockwise to the two directions (70^0 and 165^0) of equal signals from the two transmitters. Even with an *excellent* equalizer the SNR drops to almost threshold inside the two triangular arcs. For *poor* equalizer performance, essentially the case of all undesired signals and echoes outside the equalizer’s range, the two arcs where the SNR drops below threshold expand to 45^0 each. As mentioned earlier, actual performance is expected to fall between *excellent* and *poor* equalization.

Note that further attempts to provide more uniform field strength in the overlapped areas by adding additional transmitters will further degrade the SNR because it cannot be accomplished without creating new overlapped areas of self-interference.

Just how critical the adaptive equalizer performance is for successful DTS implementation can be demonstrated by examining the SNR loss in the directions of 300^0 and 120^0. In these directions (see Figure 4) the undesired signal is at minimum. At 300^0 Main/Aux = 20dB and at 120^0 Aux/Main = 26dB. Note that these ratios are typical of high-quality antennas.

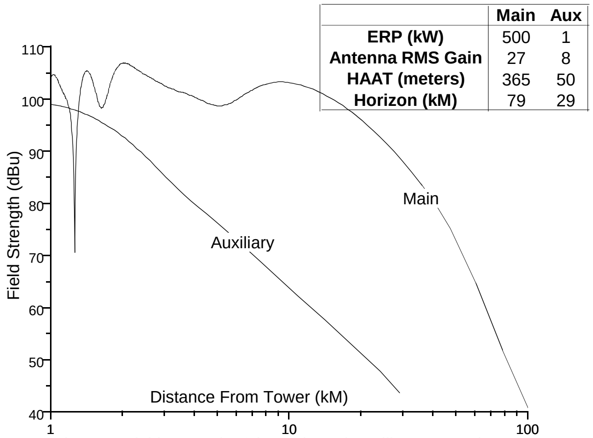
These field strength ratios are below the transmitters’ SNR of 30dB, and if the undesired signal were outside the equalizer range, it would result in a significant reduction in the composite SNR of the *poor* adaptive equalizer as shown in Figure 7. With an *excellent* equalizer, the composite SNR remains at 30dB in most directions. Just how well ATSC adaptive equalizers perform in the real world rather than in laboratory tests is data not publicly available.

Increasing each transmitter’s inherent SNR would improve to the composite SNR. It was reported earlier that for best DTV service the transmitter’s SNR should be raised to the maximum possible because the ATSC’s recommended SNR of 27dB limits the dynamic range of the receiver when the propagation channel is too noisy [6]. In the case of multiple transmitters, raising the transmitter SNR is even more important.

V. SELF-INTERFERENCE EXAMPLE II: LOSS OF SNR ALONG A RADIAL

In this example we consider two synchronized transmitters, the Main transmitter radiating 500kW and the Auxiliary radiating 1kW. The Main's radiation center is at a height of 300m and the Auxiliary's radiation center is at a height of 50m above average terrain. The Auxiliary transmitter may be viewed as a "gap-filler" or as a provider of "more uniform field" meant to improve the coverage of the Main transmitter.

The field strengths of the Main and Auxiliary transmitters are shown in Figure 8 along an arbitrary radial from each transmitter. Even though the power ratio of the two transmitters is 500:1 or 27dB, the differential maximum field strength is only 5dB at 1kM. This is primarily due to the height of the Auxiliary antenna, which is only 50m compared with 365m for the Main antenna. Note that for the first 15kM the field strength of the Main transmitter is relatively uniform at over 100dBu.



	Main	Aux
ERP (kW)	500	1
Antenna RMS Gain	27	8
HAAT (meters)	365	50
Horizon (kM)	79	29

Figure 8: Field Strength of the Main and Auxiliary Transmitters Based on FCC F(50,90) Propagation Curves

For the purpose of this analysis, the two transmitters must be separated and therefore, in order to show the overlapped coverage areas, the distance scale must be changed from logarithmic to linear as shown in Figures 9 and 10.

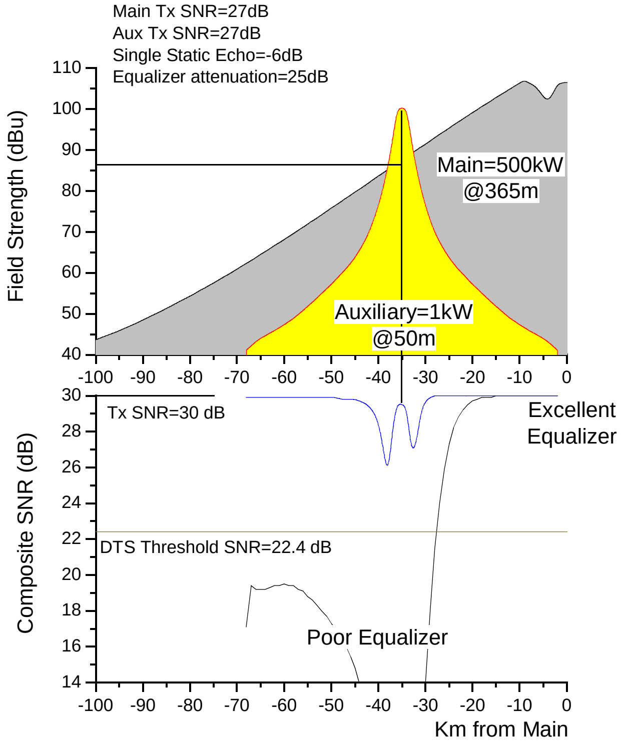


Figure 9: Field Strength and SNR Loss on a Radial Auxiliary transmitter 35kM away

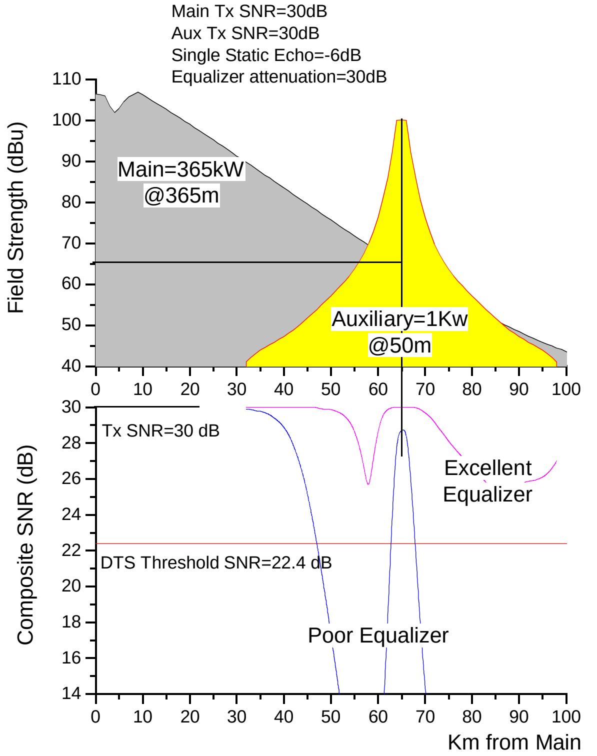


Figure 10: Field Strength and SNR Loss on a Radial Auxiliary Transmitter 65kM away

In Figure 9 the Auxiliary transmitter is 35kM away from the Main. It was positioned at that distance to raise the field strength to near a 100dBu, the estimated signal for reliable indoor reception and also to provide a more uniform field strength over a larger distance from the Main's tower. However, when SNR analysis is added it can be seen that self-interference has resulted in severe loss of SNR depending on equalizer performance. Thus, “more uniform” field strength was accomplished over a small area at the expense of lost SNR over a much larger area.

When the Auxiliary transmitter is further away and nearer the end of coverage of the Main transmitter, as shown in Figure 10, the basic tradeoff of increased field strength for lower SNR over a wide area remains. Only a relatively small area, where the Auxiliary signal is stronger than the Main’s by 30dB, around 65kM, would benefit from increased field strength and minimal loss of SNR. SNR/field strength tradeoff is thus shown to be unavoidable inside the overlapped coverage area of the Main and Auxiliary transmitters.

The radius of coverage area of the 1Kw Auxiliary transmitter is 33kM. Tilting the peak of the antenna’s main beam heavily below the horizontal would reduce this radius. This would reduce but not eliminate the interference and loss of SNR in the areas where the two signals overlap.

If the transmitted power of the Main were lowered from 500kW to 1Kw, the same level as the Auxiliary’s power, the degradation shown in Figure 9 will remain. The degradation shown in Figure 10 will disappear because the signals of the two 1Kw transmitters, separated by 65kM, will not overlap. In the latter case, the signal strength over 30 ± 25km on that radial will be too low or marginal for reliable reception.

VI. RELEVANCE OF THE FCC’s COCHANNEL INTERFERENCE PROTECTION RATIO

Were the FCC to recognize that self-interference generated inside parts of the overlapped coverage areas of on-channel transmitters, the rules and regulations governing DTS construction permits would have to be changed to protect the public from “cherry picking” the preferred service and interference areas by DTV broadcasters. Here’s why:

The FCC’s protection ratio for market-to-market cochannel interference is [7]:

$$\left[\frac{Desired}{Undesired}\right]_{MIN}(dB)=15-10Log[1-10^{(15.19-S/N)/10}]$$

$$for\ S/N<28dB$$

$$\left[\frac{Desired}{Undesired}\right]_{MIN}(dB)=15\quad for\ S/N\geq 28dB$$

Presumably, *S/N* is the ratio of the desired signal to the thermal noise floor of the receiver.

This *[D/U]* ratio states that at the threshold of visibility the *Undesired* signal may be as high as –15dB below the sufficiently strong *Desired*. For weak *Desired* the interfering *Undesired* must be lower than –15dB and the ratio is no longer a constant but a function of the *Desired*’s *S/N*. It is based on laboratory tests that excluded strong signals and multipath typical of overlapped coverage areas of DTS.

A graphic representation of the FCC’s protection ratio is shown in Figure 11 as an overlay on Figure 2. In particular, the range of Auxiliary/Main where self-interference, depending on the quality of equalizer, would be unprotected, is highlighted.

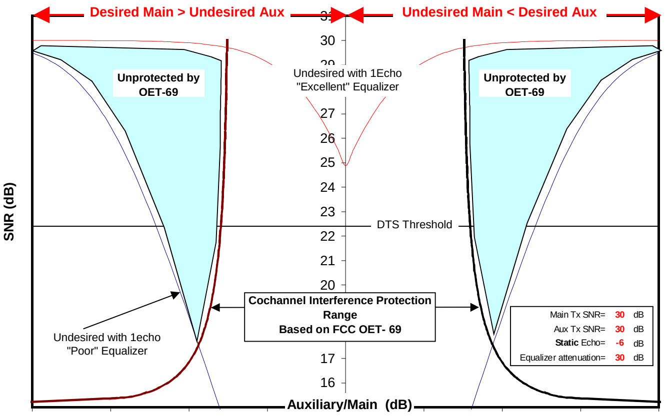


Figure 11: SNR Loss for On-channel DTS vs. FCC Protection Ratio Against Cochannel Interference

Specifically, when the *[D/U]* ratio along the SNR threshold level is between 16dB and 25dB, the FCC protection ratio against cochannel interference does not apply. At a minimum, the 15dB value in the FCC’s equation should be replaced with 25dB to protect the public from self-interference by DTS.

VII. CONCLUSIONS

The Achilles’ heel of on-channel distributed transmitter are the areas where signals from two or more transmitters overlap. In the overlapped signal areas the receiver must choose the *Desired* signal and either eliminate the *Undesired* and all multipath or coherently add the *Undesired* and all multipath with the *Desired*.

COFDM signals were designed to have a variable guard interval that allows coherent addition of echoes with the primary signal and thus raise the SNR margin. Thus COFDM is ideally suited for single frequency networks.

ATSC (8-VSB) signals require complex equalization that at best attenuates but does eliminate undesired signals and multipath. There are no ATSC equalizers currently installed in consumer products capable of coherently adding dynamic undesired signals and echoes with the desired signal. Therefore, the composite SNR in the overlapped signal areas is always lowered.

In this paper, self-interference and loss of SNR are shown to be major causes of DTV reception degradation inside the overlapped coverage areas of multiple, on-channel, distributed transmitters. The only way to avoid self-interference and the consequent loss of SNR is to design DTS with minimal or no overlapping signal contours in terrain-shielded areas.

Further, this paper demonstrates that DTS analysis should not be based solely on the combined field strength of the multiple transmitters and that, in the overlapped coverage areas, the composite SNR loss must be mapped onto the field strength for proper performance evaluation of DTS.

As shown in Figure 5, the overlapped signals also cause a significant reduction of the ATSC pilot in some areas. The loss of pilot magnitude combined with the loss of SNR margin opens the door for external interference by man-made noise and 2nd and 3rd order FM interference to emerge as significant killers of ATSC-DTV reception.

As shown in Figure 10, for a “successful” DTS, where the field strength is being raised from weak to strong without significant loss of SNR, the dominant signal must be 30dB higher than the undesired signals. Even so, “cherry picking” of areas to be penalized by loss of SNR is a necessary byproduct of DTS system design.

Finally, the FCC’s OET-69 should be expanded to include proper protection ratios specifically for DTS.

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