

TechNotes

Technical Reference for the RF Engineer from the RF Experts

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Distributed Translator Systems

This TechNote is derived from David Hershberger's whitepaper entitled "The ATSC Distributed Transmission System and Applications to Translator Service," a complete copy of which can be found in the "TechNotes" section at www.axcera.com. Dave will be presenting an extended version of this paper Monday, April 19 during the engineering sessions at NAB 2004.

Introduction

As described in TechNote 12, distributed transmission is single frequency network technology applied to the ATSC system for digital television. Rather than using a single transmitter, multiple transmitters, synchronized in frequency and symbol emission, are used to service a coverage area. Timing adjustments allow optimization of the system to produce minimum timing skew in areas where the multiple signals overlap.

This TechNote describes a method of applying distributed transmission to translator systems, creating distributed translator networks. In a distributed translator network, the translators may all operate on the same channel, resulting in greater spectral efficiency when compared to the analog translator model of today.

A Review of DTxN

Distributed Transmission is the use of multiple transmitters to service a coverage area rather than the traditional single transmitter system, or "big stick" approach.

Distributed Transmission is not a booster or repeater system. Distributed Transmission systems can not normally receive a signal off-air and retransmit it, because this would violate causality. Distributed transmission systems radiate the same symbol sequence at very nearly the same time from each transmitter. The relatively long time delays associated with demodulation, deinterleaving, and error correction, followed by forward error correction, interleaving, and remodulation, would mean that a distributed transmission slave would need the input data long before it could receive it over the air.

On-channel repeaters, on the other hand, receive an off-air signal and retransmit it within about a microsecond. Most of the delay in an on-channel booster is from the IF bandpass filter (usually a SAW filter). Because the delay of an on-channel booster is intended to be short, it is not possible to regenerate the data and remove errors. Received signal distortions (including the short echo produced by the booster itself) are cumulative and are simply retransmitted.

A distributed transmission system transmits a pristine signal from all of its transmitters, and each transmitter can be delayed or advanced in time with respect to the other transmitters in the network. On-channel repeaters can only be delayed.



Translator Dilemma

In some areas, particularly in the west, there are many translators on the air. However, even in relatively unpopulated areas, there simply are not enough channels available to provide DTV translator service at the same level where NTSC translator service already exists. This situation will only get worse with the upcoming reallocation of UHF channels 52 through 69.

In a traditional translator system, many channels may be used in addition to the originating channel. This is not an efficient use of spectrum. A more efficient use of spectrum would be to use just one additional channel for the translators, by applying distributed transmission technology.

DTxN technology is based on the use of studio to transmitter links (STLs) to transmit the modified SMPTE 310 data to all of the transmitters in a network. This is acceptable, and even desirable, for many applications. But translator systems are intended to receive signals off the air and to retransmit them on another channel. As originally conceived, the distributed transmission system did not support off-air operation. However, some new ideas have been developed which can make distributed translators possible.

Maintaining Network Data

In a DTxN, the slave transmitter removes the trellis codes from the signal before transmission, as shown in figure 1. This is necessary in order to ensure that all of the transmitted signals are identical, which is crucial to the operation of a DTxN. The result is that when the DTxP is put on the air, the trellis coder state information is lost. That means that downstream transmitters do not have access to the trellis codes. Without the trellis codes, such downstream transmitters would all turn into mutual jammers, since they would be transmitting different symbol streams from one another.

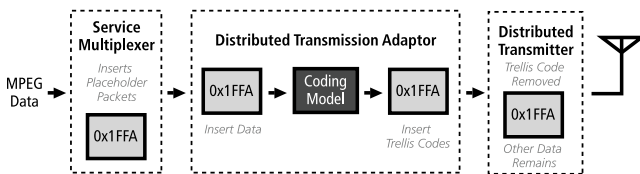


Figure 1 Life Cycle of a Distributed Transmission Packet

Fortunately, there are solutions to this problem. The nature of the solution depends on the complexity of the translator system. If the translator system is simple (meaning single hop translators only), then the solution is simple. If the translator system is complicated (multiple hop) then the solution is a little bit more complicated.

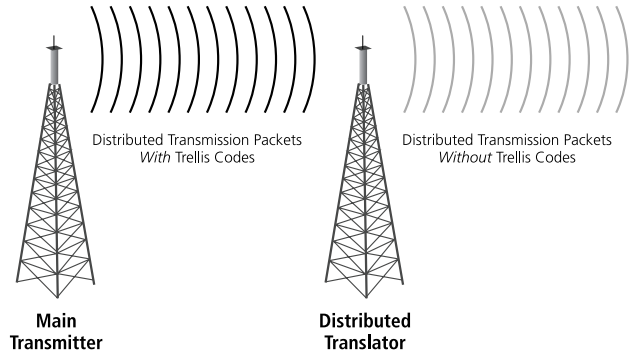


Figure 2 Single Tier Distributed Translator Network

Let’s consider the simple translator system first. In the simple system, we have a “main” transmitter and a number of translators in surrounding areas. All of the translator sites can receive the signal from the main transmitter.

In this example, shown in Figure 2, assume that the originating station is on channel 8. All of the translators might use channel 41, for example. The channel 8 signal would double as the “STL” to all of the channel 41 transmitters. There is only one main transmitter, and it alone is on channel 8, so it does not need to synchronize with anything. The DTxP, carrying the trellis codes and other necessary information, would be transmitted over the air by the channel 8 transmitter. Since the channel 8 transmitter is operating as an ordinary ATSC transmitter, it will not change the data in the DTxP. The channel 41 distributed transmitters would receive the DTxPs, decode them, and adjust their timings, trellis coders and other necessary parameters in response to the commands embedded in the DTxP. The channel 8 and channel 41 transmitters will operate with different trellis codes, different symbol sequences, and different timings. But, since they are on different channels, this is not a problem. The DTxP will control only the channel 41 transmitters, and the channel 8 main transmitter will operate autonomously.

When the DTxP is received from the channel 8 transmitter, it contains all of the trellis coder state data. But when the DTxP is transmitted by the channel 41 transmitters, that data must be removed so that the trellis coders in each distributed transmitter can follow the states of the encoding model present in the DTxA. So, the trellis coder states are no longer available at the outputs of the channel 41 transmitters. This simple technique is therefore limited to “one hop.”

If we want to have a multiple hop distributed translator network, how can we get trellis codes (along with the other necessary data) sent, over the air, to downstream distributed transmitters? This concept is shown in Figure 3. There are several ways to do this, and we will discuss one method in detail.

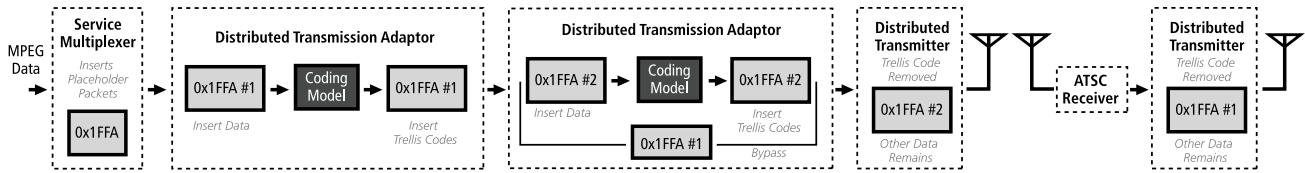


Figure 4 Multilayer Distributed Transmission System

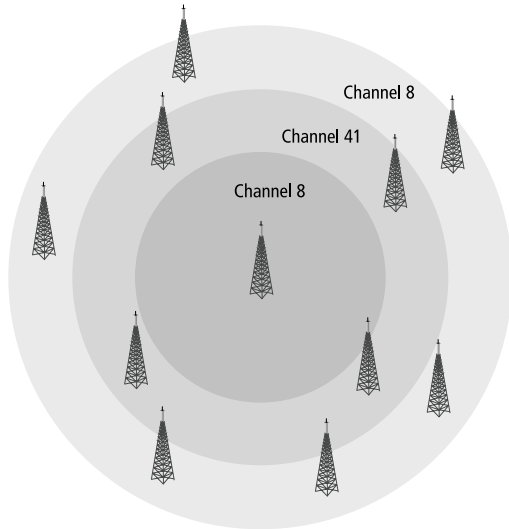


Figure 3 Distributed Translator Network Using Only Two Channels

One way of extending a distributed translator network to multiple rings of transmitters is to insert several layers of DTxPs. In effect, a number of DTxAs can be cascaded at the studio. The first DTxA inserts DTxPs for the last (outer) ring of transmitters. The second DTxA inserts DTxPs for the next to the last tier of transmitters, etc. Each tier has additional delay to allow for interleaver and other coding delays, and each tier operates with different trellis codes.

Figure 4 shows the layering of the DTxPs. Each DTxA inserts a layer of DTxPs. Each DTxA processes only the DTxPs corresponding to its tier of transmitters, and the other DTxPs bypass the encoding process. At each transmitter tier, the associated DTxPs are interpreted, and the embedded trellis codes are removed. One layer of DTxPs is required for each tier of transmitters.

Channel reuse is also possible. Extending our example, channel 8 could be the main transmitter, and the first tier of distributed translators would be on channel 41. A second tier of translators could receive the channel 41 signal, and retransmit on channel 8 (assuming that the signal from the second ring of translators does not interfere with the main transmitter). A third tier could be back on channel 41 again.

Conclusions

The ATSC system has turned out to be quite flexible and lends itself well to the creation of single frequency networks, also known as distributed transmission networks. This allows very spectrally efficient systems to be built with improved coverage and potentially lower operating costs when compared with conventional high-power transmitter systems.

It is also possible to apply this technology to translator applications as distributed translator systems, taking advantage of the spectral efficiency gains of distributed transmission and, consequently, helping to alleviate many of the concerns associated with the broadcast spectrum shortage.

The latest receivers with improved adaptive equalizers work well in a distributed transmission environment, easing system design of distributed transmission networks. However, careful system design allows such systems to work well even with legacy receivers.

Distributed transmission is another option in the digital television implementation toolbox.

Bibliography

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- 2 Hershberger, David L.; Pugh, Michael W., *Implementation of the ATSC Distributed Transmission System*. NAB 2003 proceedings, pp 280-289, 2003.
- 3 Mattsson, Anders; Weiss, S. Merrill; Simon, Mike; Hershberger, David; Wu, Yiyang; Wang, Xianbin, *Transmitter Identification Techniques for Distributed Transmission Networks*. 53rd Annual IEEE Broadcast Symposium, 2003.
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Table 1.1 Technology Comparison

	IOT	Air-Cooled Diacrode	Medium/Low Power Solid State	Low Power Solid State
Frequency Band	UHF	UHF	UHF/VHF	UHF/VHF
Cost per Watt at Low Power	High	Mid	High	Low
Cost per Watt at High Power	Low	Low	Mid to High	Not Applicable
Low Power Configuration	Driver Only 150W to 600W	Driver Only 150W	Single PA Module 400W to 700W	Complete Transmitter 50W to 3kW
Upgrade from Low Power	Add 1 to 6 IOT PA Cabinets, O/P Filters and Combiner	Add Diacrode PA Cabinet and O/P Filters	Add PA Modules and Combiner, Additional PA Cabinets if Necessary	Not Applicable
Medium Power Configuration	Single IOT 12kW to 30kW	Single Diacrode 5kW	Single PA Cabinet 2.4kW to 7kW	Not Applicable
Upgrade from Medium Power	Add IOT PA Cabinets and Combiner	Not Applicable	Add PA Cabinets and Combiner	Not Applicable
Maximum DTV Power Capability	Single IOT 12kW to 30kW	Single Diacrode 5kW	Single PA Cabinet 2.4kW to 7kW	Not Applicable
Benefits	<p>Highest final power output capability</p> <p>Best efficiency at high power</p> <p>Lowest operating cost at high power</p> <p>Can be converted between analog and DTV operation</p> <p>Can be upgraded from driver only configuration to high power with very little waste.</p>	<p>Reasonably cost effective at low power</p> <p>Best efficiency at 5kW</p> <p>Lowest operating cost at 5kW</p> <p>Can be converted between analog and DTV Operation</p> <p>Simple air-cooled design</p>	<p>Modular design allows for a wide range of power levels</p> <p>Can be upgraded from low to high power with very little waste</p> <p>Solid state devices offer extremely long life with very little maintenance</p>	<p>The most cost-effective choice at low power</p> <p>Compact design requires little floor space</p> <p>Can be converted between analog and DTV operation</p> <p>Can be converted to translator/booster or used as a transmitter backup</p> <p>Allows latest technology purchase in future for full power</p>
Drawbacks	Driver-only configuration limited to very low power and relatively expensive (cost per watt)	Driver-only configuration limited to very low power Final output power limited to 5kW	Low efficiency results in relatively high operating cost at higher power levels Multi-cabinet systems require substantial floor space.	Can not be effectively upgraded to a high power transmitter

