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Technology White Paper

Converting from Analog to Digital Broadcast System

EDX Wireless Tel: +1-541-345-0019 | Fax: +1-541-345-8145 | info@edx.com | www.edx.com

Converting from Analog to Digital Broadcast Systems

Brian Cochran, Director of Support
EDX Wireless, LLC
Eugene, Oregon USA
May 2010

Overview

Moving from analog to digital television has many advantages, but provides some unique challenges.

The benefits of DTV include:
- Long term operating costs can be lower
- Better delivered signal quality and better C/I+N (SNR) ratios
- Ability to tailor channels for greater range or greater capacity
- Ability to offer more channels (programming) in the same bandwidth/spectrum
- Greater flexibility in delivered audio/video quality
- Can free up valuable spectrum for police/fire/safety or other applications
- Greater control over Digital Rights Management

The disadvantages of DTV include:
- Initial cost of startup/transition to DTV can be expensive
- Not as resistant to multipath interference as analog networks
- Signal quality does not degrade gracefully as in an analog system
- Additional planning is necessary depending on type and mix of content offered
- Additional planning is necessary to achieve required C/I+N (SNR) and guard band ratios

While there are many DTV standards, 4 technologies are currently being deployed:
DVB-T/H - Australia, Europe, SE Asia, Columbia
DMB-T/H - China
ISDB-T/H - Japan, South America, Philippines, Brazil
ATSC - North America

Table 1 is a summary of the 4 systems currently being deployed:

Standard	Channel Bandwidth	Sub-Channels	Modulation Type	Effective Data Rate
ATSC	6mhz	up to 6	8VSB	19mbps
DMB	6mhz	up to 6	TDS-OFDM	19mbps
DVB	5,6,7,8mhz	2048, 4096, 8192	COFDM	5-32mbps
ISDB	6mhz	5617	COFDM	19mbps

The ATSC standard (8VSB modulation) defines the resolution, aspect ratio, scanning method and frame rate for display. This is commonly known as 720p or 1080p HDTV. It also defines the way audio, video and other data is multiplexed together for modulation and transmission. It is designed to use legacy analog broadcast frequencies and channel bandwidths,and can be divided into 6 sub-channels depending on the video resolution. In the US its common for a television station offer channels X.1, X.2 and X.3, with X.1 being the HDTV stream, and .2, .3 being standard definition or radio/music/other streams.

The DMB standard in China is very similar to the ATSC standard, although it utilizes an OFDM modulation scheme. The other major difference from ATSC is the addition of components that provide greater flexibility with the manufacture of consumer equipment.

The DVB and ISDB standards (OFDM modulation) don't define the type of content packaging like ATSC, rather it defines how any content is multiplexed and transmitted over the channels. The main difference between DVB and ISDB is how the sub-channelization occurs. DVB has three modes for subcarriers, a 2k, 4k, and 8k mode, which is an abbreviation for the number of sub-carriers available. ISDB has 5617 sub-carriers that are divided into 13 channel segments. DVB and ISDB have profiles for terrestrial (stationary) receivers and mobile receivers, while ATSC and DMB do not currently support mobile devices.

System Design

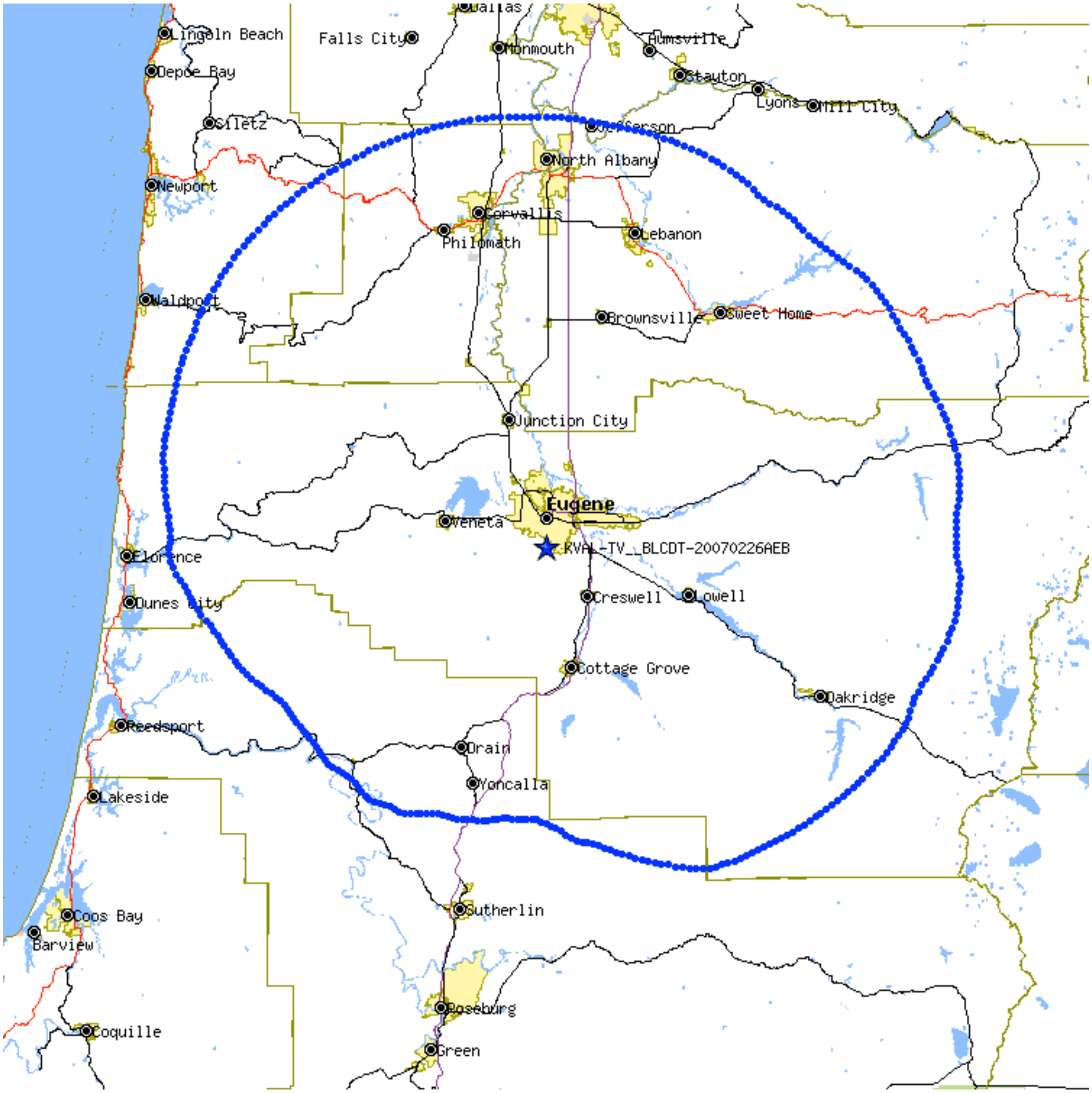
DTV networks are usually one of two types: Multi-Frequencies Networks (MFN), or Single Frequency Networks (SFN). In the United States broadcast television is supplied by private companies, each competing in the same geographic market. This dictates the approach of MFN networks; where you are covering potentially discontiguous areas and have greater potential interference issues.

In Europe, television transmission is commonly provided by government agencies or consortiums. With these agencies providing all television services the use of SFN networks become a better option, which we'll cover in the next section.

MFN Networks

For multi-frequency networks in most developed countries the licensing/spectrum management body has requirements in place for placing sites and demonstrating compliance for licensing. In North America this requires demonstrating that proposed service contours do not interfere with other stations in the area.

Figure 1 shows a contour map from the FCC database that was submitted as part of the licensing process (ATSC) for KVAL channel 13.1:

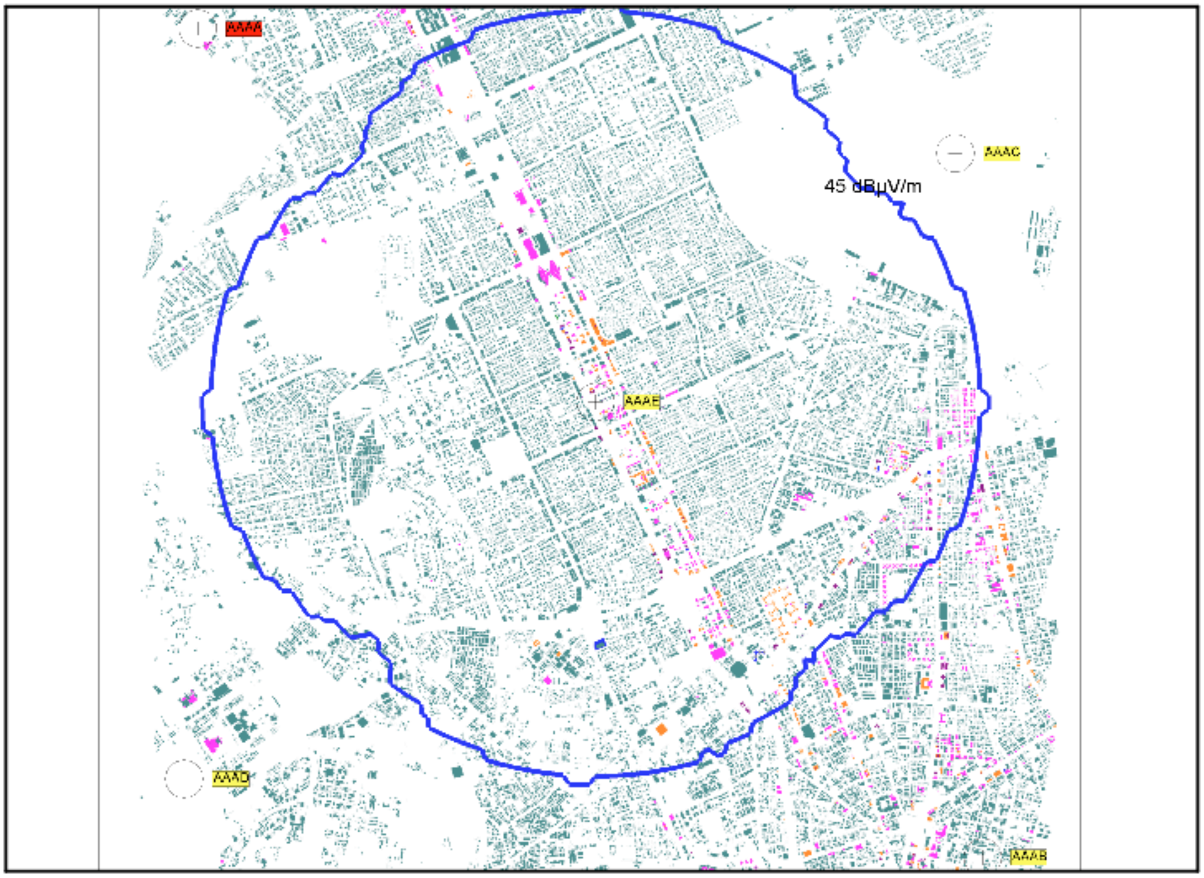


Creating service contour maps in EDX software is a simple study, and the process is well defined within the industry. The design complexity can come from interpreting the FCC rules, and balancing EdRP for coverage within the limits of your service area and competing systems.

For the following studies the study area is Riyadh, Saudi Arabia. Study area is urban, 11km x 11km. Using 30m terrain data, 1m clutter data, and a building database. Transmitters are at

350mHz, 6mHz channel bandwidth, with an EdRP of 500W. Receiver noise floor is at -102.8dBm. We're assuming a brand-new installation, not an addition to an existing system.

Figure 2 - service contour study in Riyadh Saudi Arabia:



SFN Networks

Single frequency networks are networks where all the transmitters in the system are broadcasting the same information at the same time on the same frequency. The transmitters are synchronized with each other, and in the case of DTV-B(T/H) the systems uses GPS clock timing to synchronize the transmitters. With the DVB system, you can choose the number of subcarriers wanted, and this choice of subcarriers will impact the numbers of transmitters we need, as well as the allowable maximum simulcast delay to ensure the received carriers can be decoded correctly.

Table 2 lists the maximum delay spread allowable for different Guard Intervals:

Guard interval lengths and respective safety distances

Guard Interval	FFT = 2k	FFT = 4k	FFT = 8k
1/4	56μs/16.8km	112μs/33.6km	224μs/67km
1/8	28μs/8.4km	56μs/16.8km	112μs/33.6km
1/6	14μs/4.2km	28μs/8.4km	56μs/16.8km
1/32	7μs/1km	14μs/4.2km	28μs/8.4km

Looking at the above chart, notice that the delay spread has a corresponding distance that can be used for initial dimensioning as well.

To design an SFN system then, there are three components that are of primary concern:

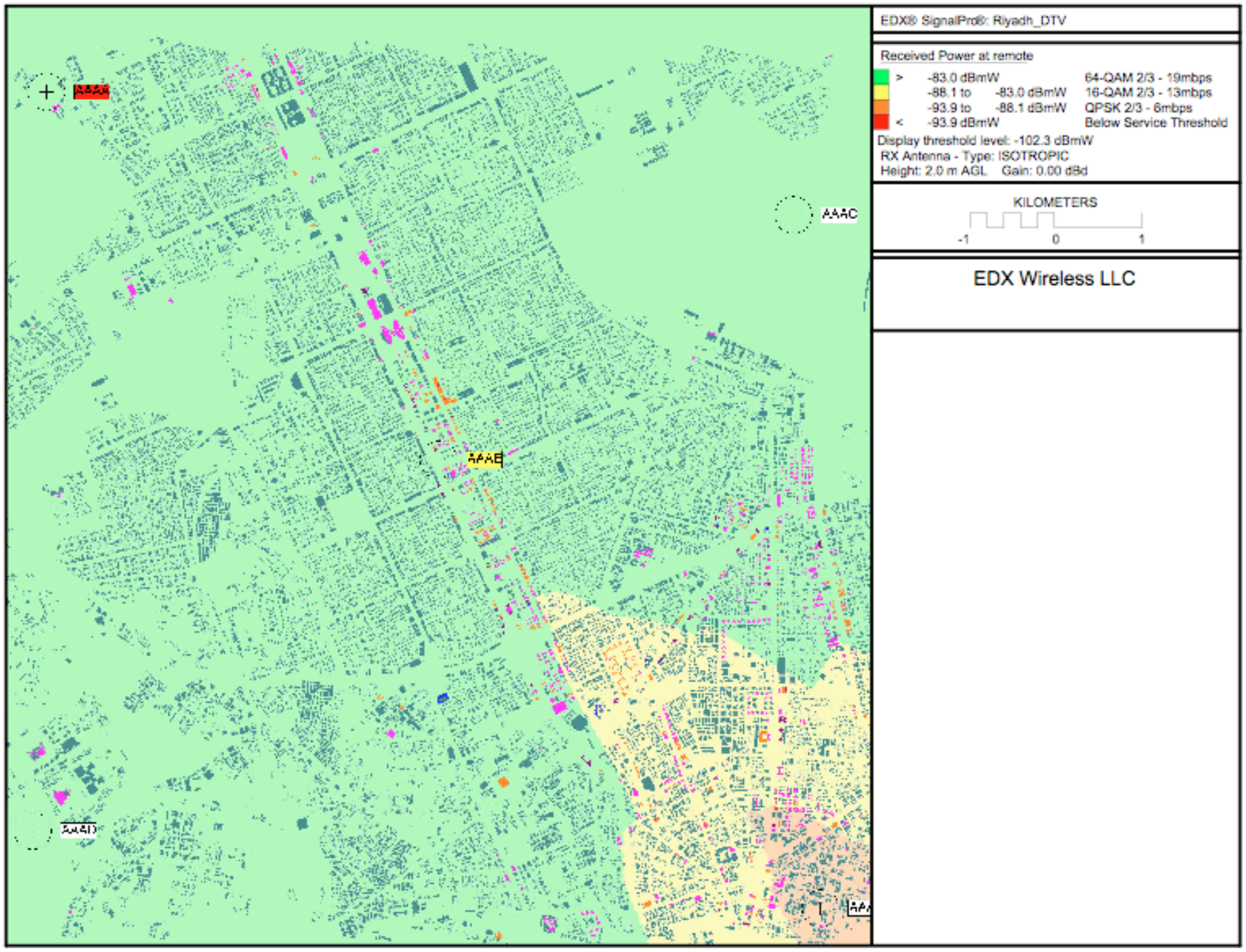
- Received power - is there adequate raw signal level to cover our service are?
- Carrier to noise ratio (CNR/SNR) - is there adequate signal level above noise and other interferers?
- Simulcast Delay - how is the signal delay in the system going to affect my choice of guard intervals?

Initial Dimensioning

To start, assuming there isn't list of available locations, there are two choices for initial design. In one approach a few transmitters can be placed and a received power study run to see how much of the service area has been covered, making adjustments from there. In the second method, recalling the chart above, if the desired coding rate is known, the safety distance could be used to place transmitters within that distance of each other. For this paper, a specific FFT size or guard interval has not been chosen, rather, all available ranges will be displayed as opposed to a specific type.

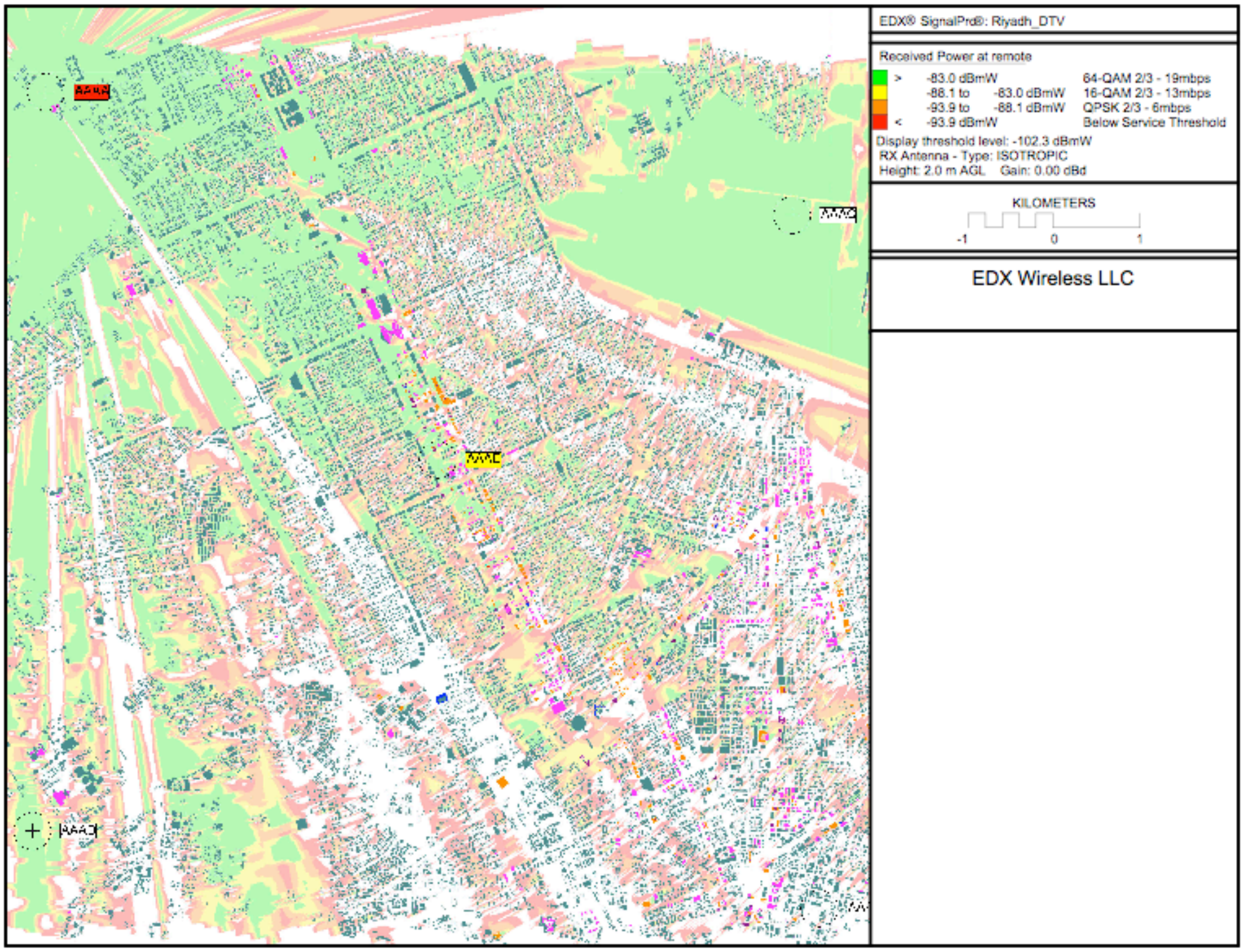
Approach 1 (received power method) will be used to determine transmitter placement. For the first pass, Okamura-Hata is the propagation model used, with a 6dB margin and a single transmitter. Okamura or ITU-R are good propagation models if all you have access to is terrain databases, or it's required by your company or governing agency.

Figure 3 shows the results:



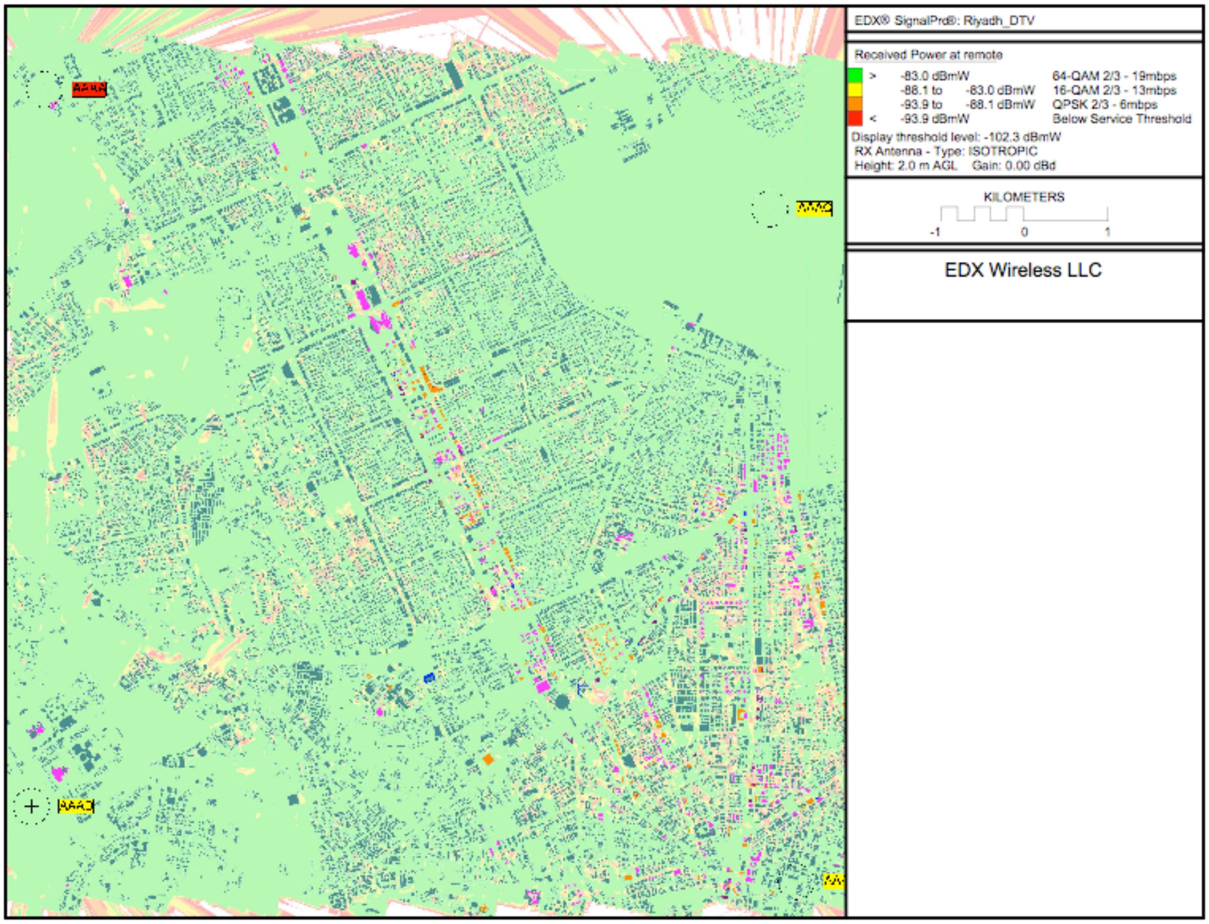
As you can see, it looks like there is good coverage with one transmitter. However, let's look at the same issue, but this time using clutter and building databases.

Figure 4 shows the results using the Free Space + RMD propagation model and one active transmitter:



Using the higher resolution databases, you can see there is a much greater coverage problem. The advantage of using high resolution databases studying urban coverage becomes evident; however, it’s important to note that these databases are not always easily available, and can be quite expensive depending on the size of area and detail required.

Figure 5 shows the results of adding three additional transmitters:



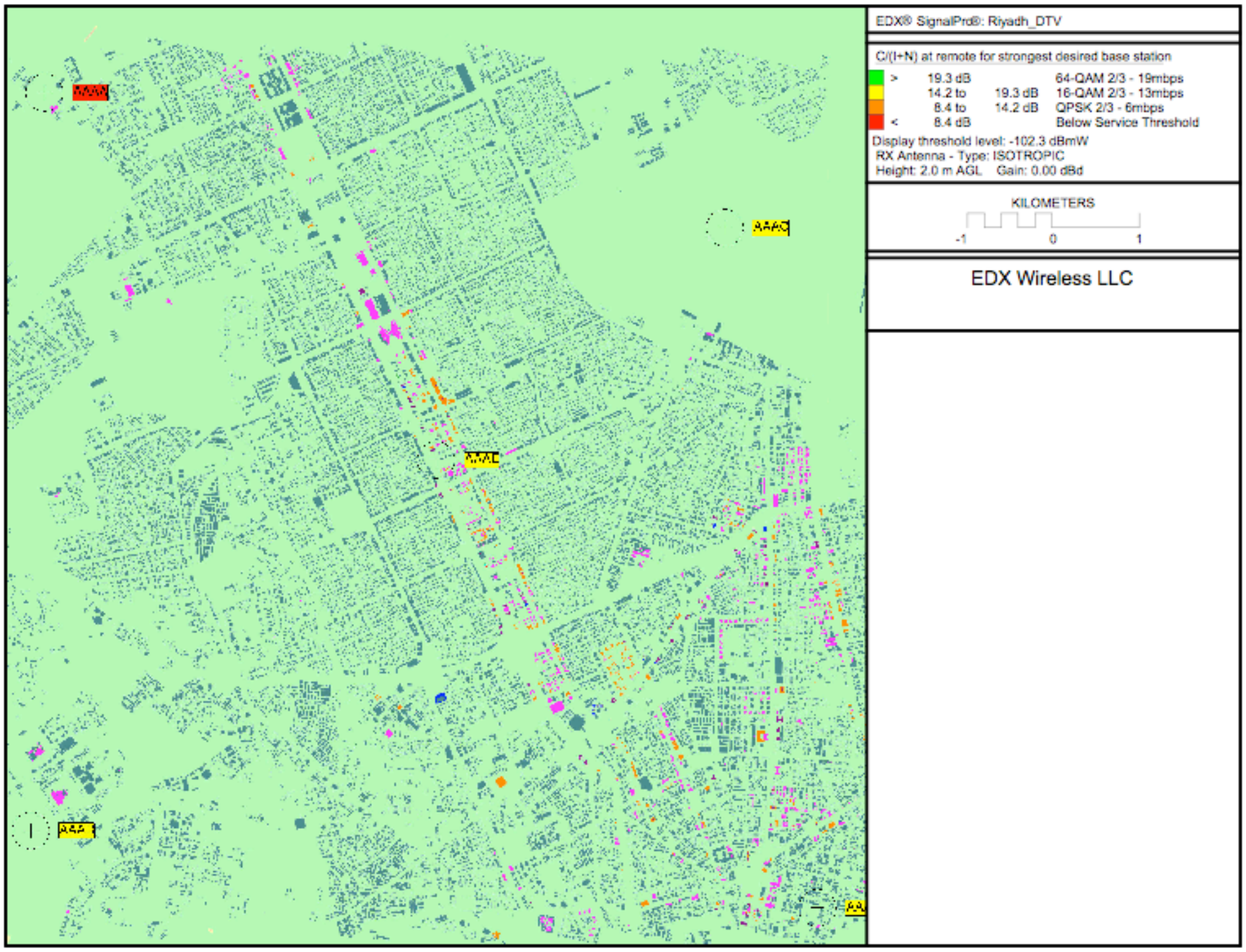
Capacity Design

Once we have adequate coverage, we can look at other aspects of the system. Table 3 shows required CNR's for different modulation types with a guard interval of 1/4 (a more comprehensive table can be found at the end of this document).

Examples of CNR requirements for 6mHz Channel - DVB-H (Note DVB-T may be different)

	Code Rate	Bit Rate (GI = 1/4)	C/N (dB)
QPSK	1/2 2/3	3.73 4.97	5.4 8.4
16-QAM	1/2 2/3	7.46 9.95	11.2 14.2
64-QAM	1/2 2/3	11.19 14.92	16 19.3

Signal to noise + interference studies can be used in EDX to look at areas that may fall below the type of service required. From the above chart, if you are designing for 64-QAM 2/3 with a guard interval of 1/4 and a bit rate of 15mbps, then a CNR of at least 19dB would be required to achieve that service level. Figure 6 shows a CNR study for the five transmitter DVB-H system:



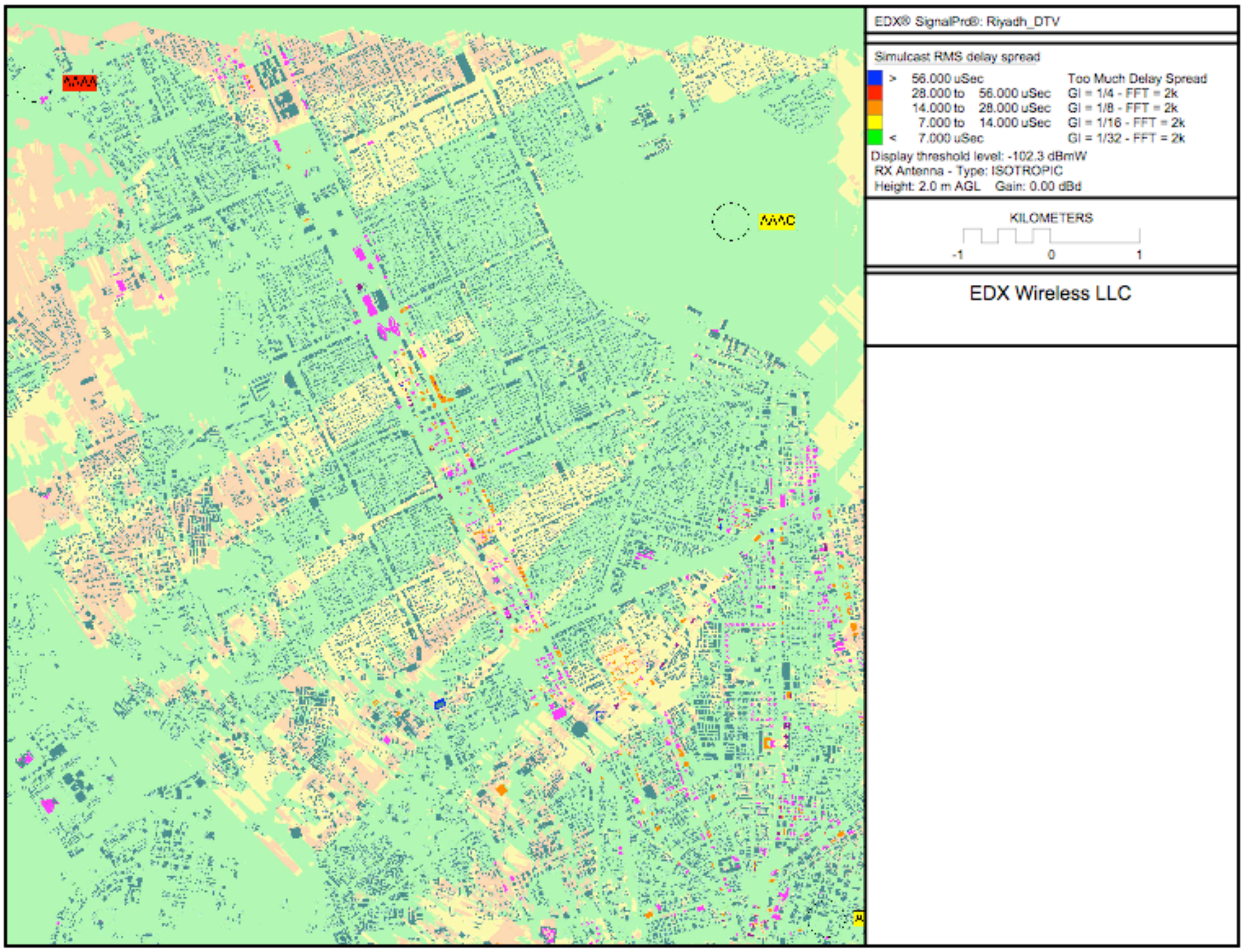
In this scenario, it's assumed there are no other transmitters in the area that could be interfering with the system, so the study is showing signal level above the noise floor. The breakpoints have been set to correspond to the minimum CNR required for the different modulation types in DVB-H. If other interferers are present, can be defined and entered in to EDX software, the study can be re-run including interference + noise to find problem areas.

While this paper doesn't show CNR ratios for all the modulation coding rates, using the table at the end of this paper you can extrapolate likely ratios. Referring back to table 3 on the preceding page, you'll notice that the required C/I+N goes up 6dB+/- for each jump in coding rate. Using the bit rate table at the end of the chapter, generalized CNR values all the way up to 64=QAM 7/8 modulation rates can be extrapolated.

Once it's been determined that there are enough towers for adequate coverage and adequate signal to noise + interference for the service you are designing the next step is to examine how choice of guard interval will affect the system. Remember from table 1 that the choice of

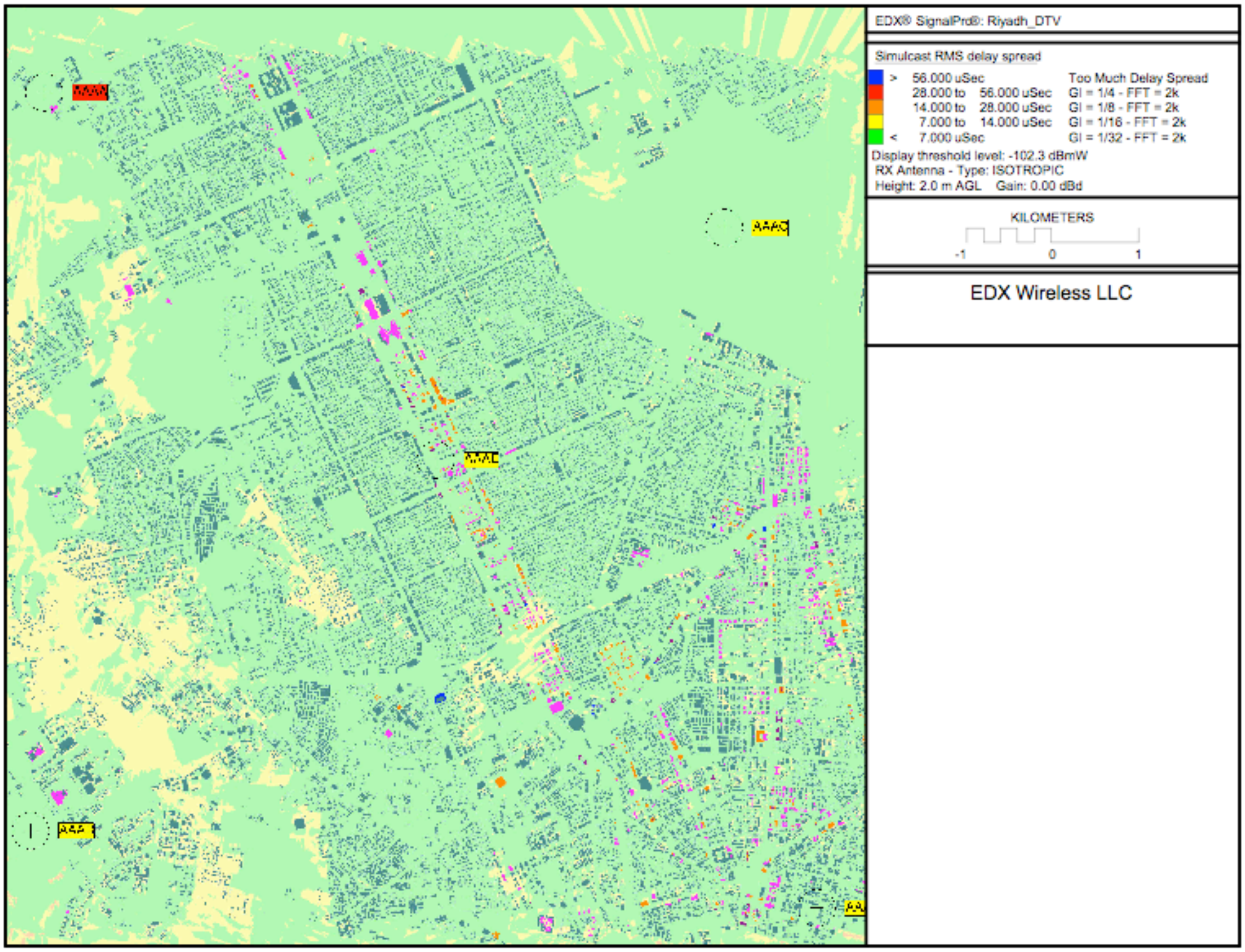
FFT size and guard interval impact the maximum allowable delay spread for each service type. If the delay at the receiver exceeds the maximum spread allowed, there is a high likelihood that service delivery will fail due to one stream colliding with another sites transmission stream that falls outside the guard interval.

Looking at the three site system, here are the results for different guard intervals. Figure 7:



As can be seen, as our guard interval is shortened, the maximum allowable distance between the transmitters decreases. Remember, by shortening the guard interval higher data rates can be achieved (depending on modulation type and coding rate). Shorter guard intervals increase the possibility of data from two different transmitters conflicting at the receiver, which by definition, reduces the effective coverage range for those transmitters. Guard interval choice is a trade off between data rate and size of coverage area for each transmitter.

Figure 8 shows how adding two additional transmitters allows us to reduce the guard interval:



Summary

Designing digital TV coverage isn't that different from traditional analog systems. It is still important to accurately predict the received signal levels, especially for service in urban areas. Since digital reception is either sufficient (user receives transmission with good picture and sound quality) or insufficient (no reception) with a boundary between the two at a defined C/I+N ratio, accurately modeling the impact from other transmitters and multipath in the SFN network is also important.