Effective DVB-T Coverage

One of DVB-T's many advantages over analog technology is the mechanisms it provides for making network coverage more robust and cost-effective. Specifically, supporting indoor reception by the majority of consumers is now feasible. However, in order to make the most of DVB-T's potential, network operators need to take a fresh look at network design and implementation.

The Analog TV Network

In order to fully understand the factors impacting DVB-T network implementation it is useful to briefly go back to the legacy analog TV network as deployed starting way back in the first half of the 20th century.

A number of technical and economic limitations largely drove analog network design:

- For good reception, the analog TV signal requires a high signal-to-noise ratio. It is also sensitive to reflections due to multipath propagation (the well-known and annoying picture "ghosts"). Therefore, the network was planned for, and consumers were urged to rely on, a directional roof-top antenna that would be in line-of-sight or near line-of-site of the nearest transmitter.

- Each analog TV transmitter had to be allocated a frequency channel of its own. Frequency re-use could only be done in non-adjacent areas that were sufficiently separated by distance or terrain so as to avoid mutual interference (similarly to frequency planning in the much more recent cellular network). This motivated the use of the fewest possible transmitters, operating each at the highest possible power in order to maximize its service area.

- The very high power typical of TV transmitters limited their placement to the top of very tall towers or – much more often – altogether outside the target urban area. This, in-turn, increased the power requirement even further.

All this led to analog TV networks that consisted of a small number of very high-power (up to tens of kilowatts) transmitters, with some simple repeaters used for gap-filling in specific shadow areas or remote localities.

The Digital TV Revolution

TV's transition to digital technology presents broadcasters with new opportunities and, at the same time, provides them with new technology tools for network design and implementation:

New Technology

By making use of efficient video compression as well as modern modulation and coding, the DVB-T signal can be received, and the digital picture perfectly reconstructed, at a much lower signal-to-noise ratio than the analog waveform. Just as importantly, reception is entirely possible even in the presence of strong multi-path echoes. This means that the DVB-T network's power budget is much more favorable than the analog network's, leaving room for transmitter power reduction, increased range, or – most importantly –economically supporting indoor and even portable reception for the majority of consumer.

Another key new feature of DVB-T is Single Frequency Network (SFN) technology: when properly synchronized using standard mechanisms, multiple DVB-T transmitters, of any power level, can broadcast the same programming over the same frequency channel, even with overlap in coverage area.

The concept of SFN completely revolutionizes TV network design: with old analog technology, operators needed to use multiple frequency channels to generate wide-area coverage for a single program, and transmitter placement and power level needed to take into account multi-frequency planning and co-channel interference. With SFN, a very wide area – often the entire country – can be covered using a single channel per multiplex, and transmitter placement and power level can be planned with only signal level as a design guideline.

New Opportunities

With DVB-T's much higher efficiency and capacity, over-the-air digital TV can now offer consumers tens of Standard Definition (SD) channels as well as – especially with DVB-T2 and MPEG-4 compression – a rich High Definition (HD) offering. This, in turn, opens the door to new business models beyond the public-funded or advertising-supported free-to-air services that were the rule in the analog days. Incumbents can expand to, and new market entrants can focus on, premium, for-pay services on top of the basic free-to-air package. Allowing these services to be received with an indoor antenna becomes imperative in lowering the barrier to entry, reducing installation and support costs and differentiating from cable and satellite.

Just as importantly, with indoor and portable reception now possible, DTT providers can effectively address market segments that play to their strength in competition with cable and satellite, namely people away from home in the office or a restaurant, or consumers looking for a free and easy to set-up connection to the second or third TV set at home.

The New Network

Making effective use of DVB-T's new technology tools to address the new opportunities digital TV presents calls for a fresh look at network design and implementation:

The need to allocate a separate frequency channel to each analog transmitter drove analog network design towards single-transmitter solutions, where one very high-power transmitter covered a very large area such as a major metropolitan center. Due to radiation safety and zoning considerations, such high-power transmitters could not usually be placed close to population centers: they needed to be placed on mountain tops some distance away from their target coverage area, further increasing the power they needed to radiate.

Digital TV's lower signal power requirement together with SFN technology make it possible to break this vicious circle: a handful of SFN transmitters, operating at a fraction of the power of the old analog transmitter, can now be placed inside the target urban area, providing much better coverage at a fraction of the cost. A real-life example of this new approach to network design is illustrated in figure 1:

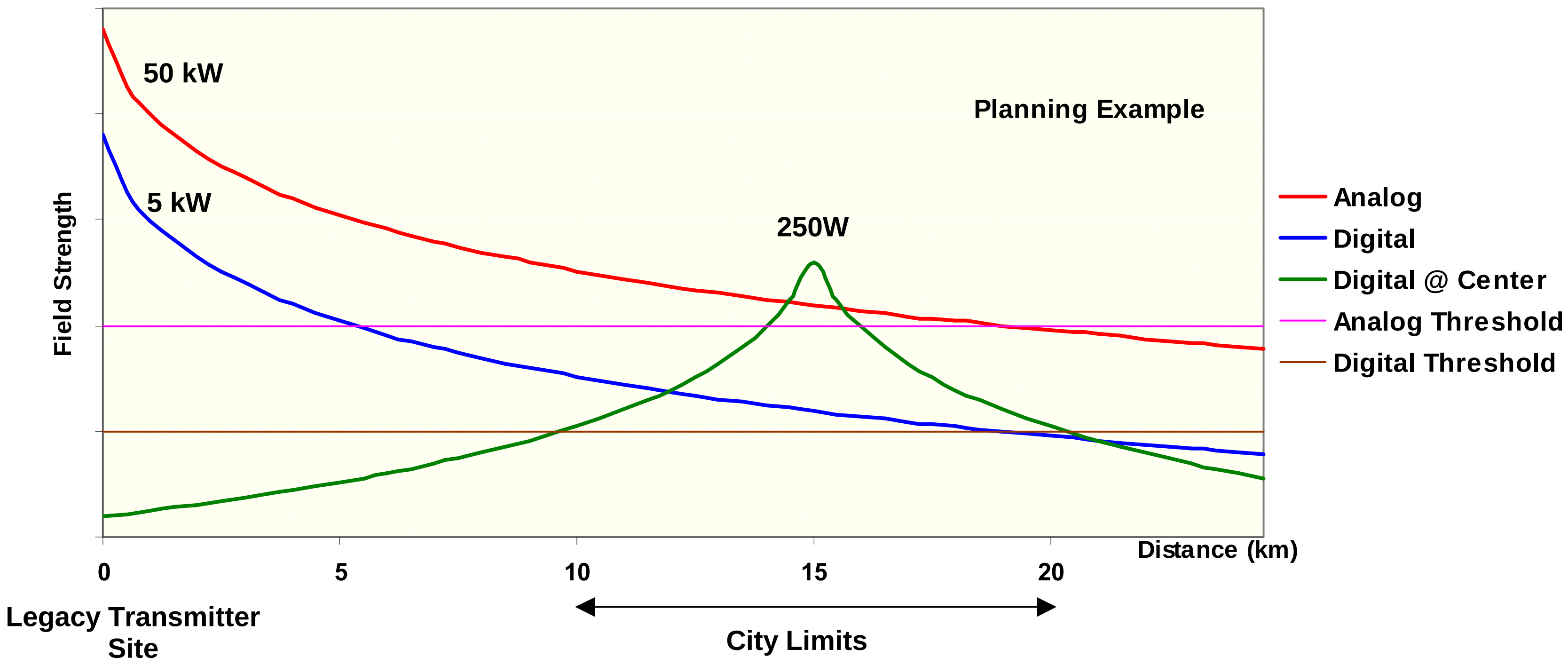

Figure 1: Digital TV Planning Example

The center of the city to be covered lies within a circle with a radius of 5 km. Due to the relatively high reception threshold of the analog signal (the thin horizontal pink line), placing the analog transmitter close to the city center was not possible. It was therefore built on a hilltop about 15 km away. This meant that, in order to compensate for the long distance to the far edge of the city center, its output power had to be increased even further, resulting in an analog transmitter with an output power of 50 kW. Finally, even with such a high transmitter power, reception within the city was only possible with a roof-top antenna.

Digital TV's lower reception threshold is depicted by the thin horizontal brown line, which lies well below the analog threshold mentioned above. If a digital transmitter were to be co-located with the analog transmitter, it's output power could be reduced in proportion to the improvement in reception threshold, resulting in an output power requirement of 5 kW.

Furthermore, placing the digital transmitter close to the city center can yield an additional dramatic reduction in power: for this scenario, an output power of 250W is sufficient to provide digital coverage of the city center. A suitable location for the installation of such a modest power transmitter can, in all likelihood, be found within the city, making it a realistic option for digital TV implementation.

Finally, with this new approach it is now possible to improve network coverage to the point where most users can use an indoor, set-top antenna to receive TV programming. While increasing the power of the old analog transmitter to allow that was not realistic, digital SFN technology makes it entirely feasible: replacing the one 250W digital transmitter with four 400W transmitters properly located around the city center – still a very reasonable proposition – can improve coverage to the point where the large majority of city residents can receive over-the-air TV using an indoor antenna – a huge gain in convenience and economics.

Transmitters and Repeaters

Low-power DVB-T sites come in two main varieties – transmitters and repeaters (see figure 2).

A transmitter is functionally similar to the legacy high-power site: it receives the content for transmission from the head-end over a distribution network (which can be satellite-, microwave- or fiber-based), and uses it to modulate the DVB-T RF carrier.

A repeater, on the other hand, receives the DVB-T signal – the same signal picked up by the end user's TV – from a nearby transmitter and proceeds to recondition, amplify and re-transmit it to cover an under-served area.

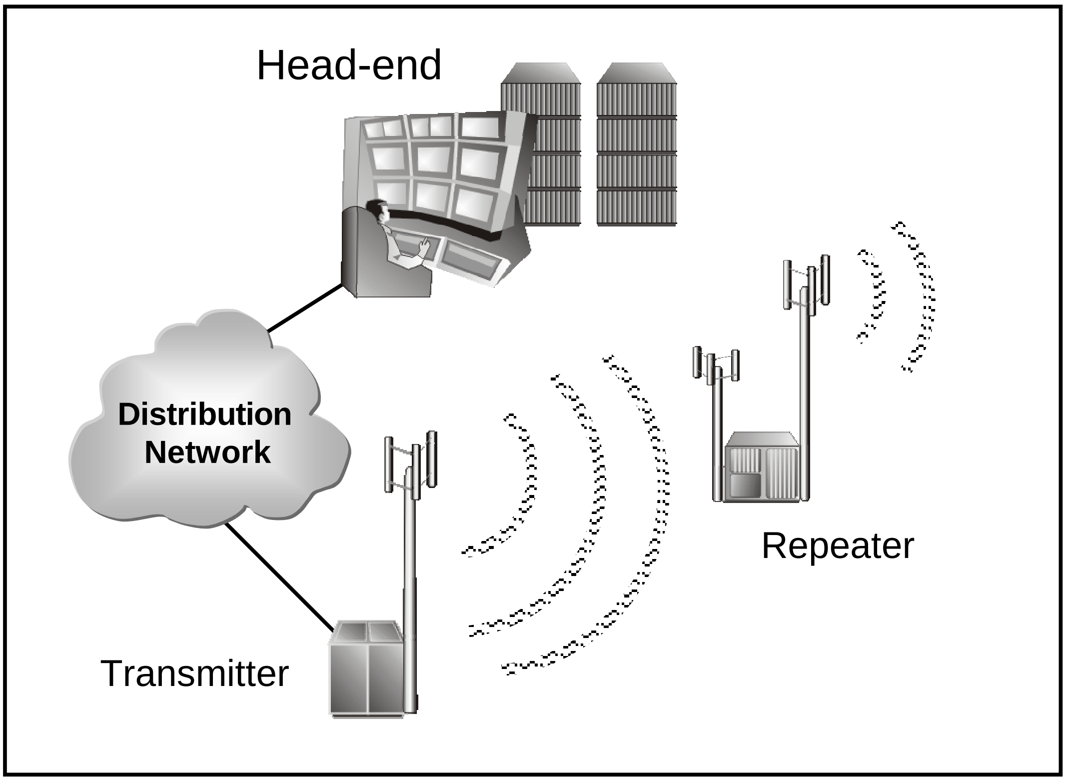

Figure 2: Transmitters and Repeaters for DVB-T Coverage

A DVB-T transmitter site typically includes the following functions:

A suitable interface connects the transmitter to the distribution network: for satellite distribution this means a satellite dish and a cable run to an indoor satellite receiver; for a wireline network this is an Ethernet, SDH, PDH or similar interface.

The received data is optionally demultiplexed, or groomed, in order to extract the relevant content. That content is then input to the DVB-T modulator and from there to the HPA, which feeds the transmit antenna.

DVB-T networks will most often work as a Single Frequency Network (SFN). In an SFN, adjacent transmitters that cover a contiguous area and deliver the same content can transmit on the same RF channel, thereby economizing on valuable spectrum resources. As long as the outputs of all SFN transmitters are synchronized to within a fraction of the DVB-T guard interval, the receiver is able to take advantage of the design of the DVB-T signal and operate satisfactorily even in locations where it receives the transmissions of multiple sites (which might otherwise interfere with each another). Synchronizing the SFN transmitters is usually done by GPS, and the transmitter should therefore include a GPS receiver and related synchronization unit.

Repeaters are conceptually simpler: their function is to receive the DVB-T signal, filter and amplify it for output to the transmitting antenna. Some repeater products can perform frequency translation: receiving a signal on one channel, they convert its frequency for output on another channel. This variation, however, is not useful in typical DVB-T networks: multiple channels are not likely to be available, least of all in networks with a large number of repeaters. DVB-T deployments will therefore most likely use what's called on-channel repeaters.

Simple on-channel repeaters are useful for indoor coverage enhancement in malls, transportation terminals etc. However, an additional complication arises when they need to provide outdoor coverage: for their "on channel" operation, such repeaters need to include a receiving antenna, an amplification chain and a transmitting antenna that outputs a signal on the same frequency as the received signal. Unless the receive and transmit antennas are properly isolated from each other, feedback from the latter to the former will cause the entire chain to oscillate. The required isolation level is often difficult to achieve when both antennas are located outdoors at relatively close proximity, especially as they are typically broad-beam. To overcome this difficulty, use is made of an echo-canceling repeater: such a repeater digitizes the input signal and then performs echo cancellation in order to offset as much as possible the output-to-input feedback signal path. The algorithms used by such echo-canceling repeaters are similar to those used to cancel out speech echoes in long-distance telephone circuits.

Transmitters and repeaters each have their advantages and disadvantages, and the optimal choice of technology depends on the specific circumstances:

A transmitter can be placed at any location that is within reach of the distribution network. When satellite distribution is used, this is practically almost anywhere. A repeater, on the other hand, needs to be within good reception range – essentially within line-of-sight – of a transmitter, and is therefore limited to service extension over a modest distance.

Repeaters rely on an input signal that's freely available over the air. Transmitters require a distribution network, with its associated set-up and operational costs. However, with satellite distribution, which is generally the method of choice for DVB-T networks, those are minimal even for a relatively small network of a several tens of sites.

The hardware cost of an echo-canceling repeater is comparable to that of a transmitter with a similar output power.

The output signal of a properly engineered transmitter is optimal in terms of having minimal noise and distortion. A repeater, on the other hand, cannot cancel out noise and distortion introduced to its feeder signal: any impairments appear at its output, limiting signal integrity. This is especially true in dense SFNs, where a repeater is likely to pick up the signals of more than one transmitter: at best, the output of such a repeater will contain multiple echoes of the DVB-T signal; at worst, the repeater's echo canceller may fail to converge, rendering it useless.

The service availability of a transmitter is dependent on that of the distribution network it connects to. On the other hand, the failure of a transmitter will bring down all the repeaters that rely on it for signal feed.

To summarize:

	Transmitters	**Repeaters**
Location	Almost anywhere	Within line of sight of a transmitter
Cost of distribution	Distribution network's cost	None
Equipment cost	Similar	
Signal integrity	First rate	Somewhat degraded, especially in a dense SFN
Service availability	Dependent on feeder network	Dependent on feeding transmitter

Current DVB-T network deployments generally favor transmitters over repeaters for wide area coverage, limiting the use of repeaters to spot coverage of indoor locales: at a similar hardware cost, and with the cost of distribution not being a major factor to the equation, transmitters offer superior signal quality and much higher flexibility in site placement.

Conclusions

DVB-T technology's new capabilities provide broadcast operators with compelling reasons to take a fresh look at network design and implementation. In many circumstances, deploying multi-transmitter DVB-T SFNs is a much better solution than a straightforward upgrade to the legacy analog TV transmitter site, providing better coverage at a fraction of the capital and operational cost.