SATELLITE/TERRESTRIAL MOBILE MEDIA SYSTEM DESIGN AND IMPLEMENTATION

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ABSTRACT

Consumers worldwide continue to demonstrate an insatiable desire for information and entertainment. In response to this demand, service providers must consider the most effective and efficient means of delivering wireless voice, video and data services. Many wireless delivery models exist, each with advantages and disadvantages. One of the newest methods for mobile television signal delivery combines the advantages of both satellite and terrestrial delivery models. Advanced synchronization techniques, along with careful system planning, allow the satellite and terrestrial signals to compliment each other, blanketing wide regions and filling in coverage gaps, approaching nearly 100% coverage within the areas served.

Implementation of a satellite/terrestrial signal delivery network requires an in-depth knowledge of the characteristics of both satellite and terrestrial networks, as well as an understanding of how these individual signals will interact with each other. For example, while terrestrial signal sources are fixed relative to each other, a satellite transmitter moves substantially within its orbit, relative to the terrestrial emitters. Known as satellite “wobble”, this effect must be addressed in order to ensure a consistent signal and avoid mutual interference. A viable system design will take this mutual interference into consideration, while simultaneously identifying the correct placement of terrestrial emitters in order to ensure optimal mobile coverage.

Adding to the system design challenge is the need to provide local content within the coverage area, while still preventing mutual interference. Because this content varies from one location to the next throughout the region, it may be necessary to implement multiple single frequency networks within each region. This paper will discuss the design constraints involved in building a successful satellite/terrestrial network, how each applies to the implementation of a successful mobile media broadcast system design, and the enabling technologies. The paper will consider the currently available satellite/terrestrial mobile media technologies, including DVB-SH, CMMB and others.

INTRODUCTION - WHY SATELLITE/TERRESTRIAL NETWORKS?

Overview

Mobile Media has become a service that has gained much attention worldwide in recent years. Multiple technology choices have been introduced, trialled, and commercially deployed, with varying degrees of success. A summary of leading technologies are noted below, along with their places of origin (1):

DVB-T/DVB-H/DVB-SH (European Union)
MediaFLO (USA)
T-DMB/S-DMB (Korea)
ISDB-T One Segment (Japan)
UMTS MBMS (European Union)
CMMB (China)
DMB-T/DTMB (China)
MPH (USA/Korea)
A-VSB (USA/Korea)

Owing to the more favorable propagation characteristics of lower frequencies, the most successful terrestrial systems have been those at the UHF frequencies, where a system can be deployed with fewer, larger cells, and better indoor signal penetration compared to L band or S band systems. This fact has been cited as a key reason for the initial success of the MediaFLO deployment in the United States (a UHF system) vs. the now-terminated Modeo deployment (an L band system).

However, new hybrid satellite/terrestrial systems have emerged that may reverse this advantage in favor of the higher frequency systems. The concept is relatively simple – serve most of the desired coverage area with a direct broadcast satellite signal, which is beamed directly to the handset, or similar receiver, and then “fill in” the areas that can not be served well by satellite (e.g. dense urban areas) with terrestrial radiator cells. Since practical satellite service is limited to frequencies at L band and higher (due to antenna size and gain), holders of these slices of terrestrial spectrum now have another alternative to provide more complete coverage.

History

Satellite/terrestrial systems are not an entirely new concept. In the Unites States, subscription radio (and recently video) services have been provided for years by XM Radio and Sirius Satellite radio. In the Europe/Middle East/Africa region, a similar service is provided by WorldSpace. However, these systems are relatively narrowband (primarily audio programming), and use separate, but nearby channels for the satellite and terrestrial components of the network. In other words, the satellite is transmitting on one frequency, and the terrestrial transmitters on another. This requires multiple spectrum allocations, and also requires a more expensive receiver. However, the services have proved to be robust, and a great deal has been learned about how to design such hybrid systems. These experiences, along with the development of new broadband technologies which allow for video services, and enable transmission on a single set of channels, have spawned a number of planned trials and deployments around the world, in both L and S bands. An examination of these new technologies is discussed next.

AVAILABLE TECHNOLOGIES

Only two technologies have currently been advanced as broadband mobile media satellite technologies – DVB-SH (Digital Video Broadcasting – Satellite to Handheld) from the European Union, and CMMB (China Mobile Media Broadcasting) from China.

DVB-SH

DVB-SH is the latest evolution of broadcast technologies from the DVB Project. It has evolved from DVB-T (terrestrial) and DVB-H (handheld), and incorporates a number of key parameters (2)(3)(4):

- Addition of 1K OFDM FFT mode and support for 1.7 MHz channels
- Forward error correction using Turbo coding, adapted from the 3GPP2 mobile telephony world
- A flexible interleaver, available from a few hundred milliseconds long up to 10 seconds
- Two modes of network architecture:
    - SH-A – OFDM on both the satellite and terrestrial links, which provides for the implementation of a single frequency network (SFN) between the two
    - SH-B – retains OFDM for the terrestrial link, but uses TDM for the satellite link; this does not allow the possibility of satellite/terrestrial SFN, and thus requires separate frequencies for the two

CMMB

CMMB is a Chinese technology (physical layer is known as STiMI – Satellite Terrestrial Interactive Multi-service Infrastructure), and is similar to DVB-SH, in that it is also an OFDM technology that provides the possibility of satellite/terrestrial SFN operation. The major differences with CMMB are that instead of Turbo coding, it uses LDPC (Low Density Parity Check) code, and that synchronization is based on a pilot training symbol, thus it is less sensitive to Doppler shifts that could otherwise use up the guard interval. In addition, CMMB does not have a TDM mode like DVB-SH; it only uses OFDM.

Note that for each of the new technologies, while they have been designed and optimized to allow hybrid satellite/terrestrial networks, there is nothing that *requires* a satellite for operation. Given the several improvements over previous terrestrial technologies, such as more robust and efficient forward error correction, better interleavers, etc., it would make perfect sense to use these technologies on a terrestrial-only network.

FUNDAMENTAL ARCHITECTURES

As discussed, the satellite and terrestrial networks can be a SFN, or can use separate frequencies. SFNs provide important advantages, and will be discussed next.

SFN

SFNs have been used extensively in terrestrial broadcast networks, especially with OFDM. A SFN means that all emitters are locked (usually by GPS) to output the same carrier frequency with identical symbols, at nearly the same time (as received at the receiver). This provides important advantages:

- Only one frequency is required to deploy an entire network of transmitters
- Instead of each cell interfering with each other, constructive addition of signals (SFN gain) can improve coverage relative to individual radiators
- Receivers can be simpler, requiring tuning to only one channel

However, it is a relatively new concept to implement a SFN that includes not only a network of terrestrial transmitters, but also a satellite. A block diagram of a typical network is shown in Figure 1 below:

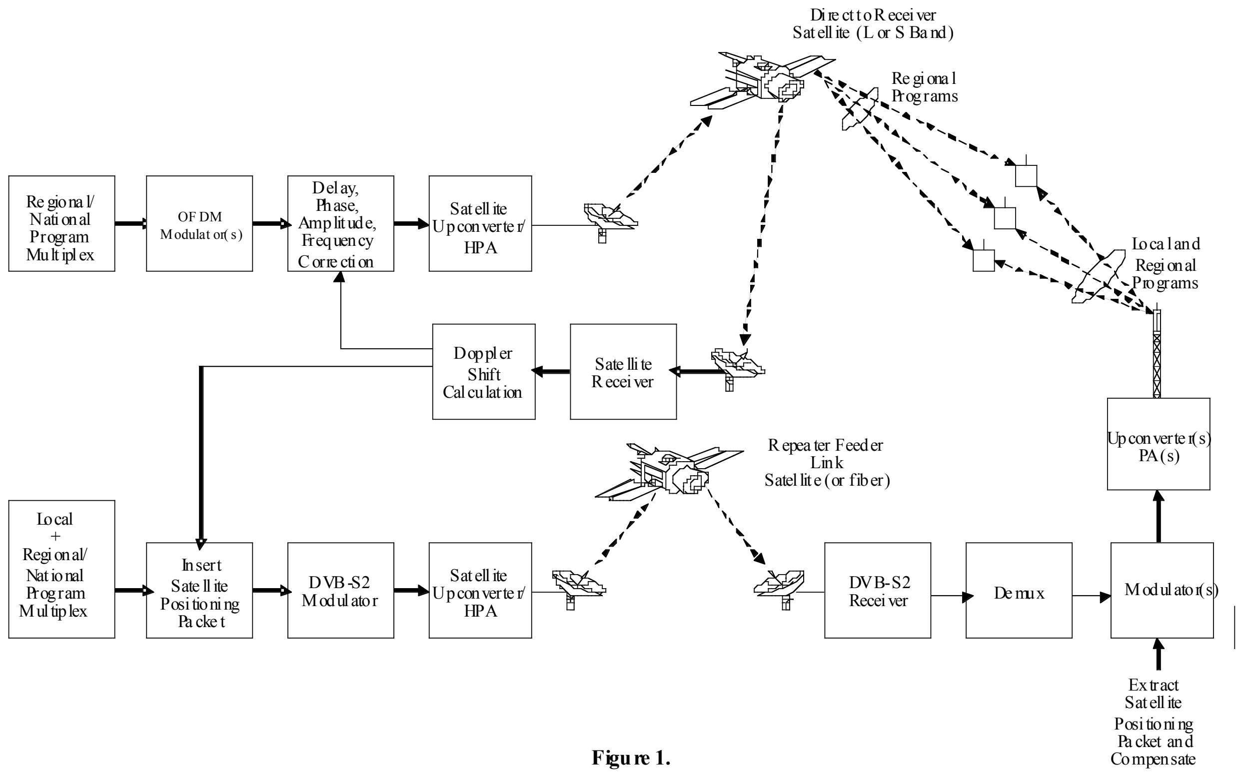

Figure 1.
Combined Satellite & Terrestrial Typical Network

Note that there is a separate link (satellite in many cases) to deliver the program signals to the terrestrial repeaters – they cannot be fed by the satellite link that feeds the receivers directly. This is because the satellite and the repeaters must be fed in parallel – otherwise, there would be no ability to adjust delay independently.

The satellite provides a direct link to the receivers, and would presumably provide ubiquitous coverage. However, in urban or suburban areas, buildings or other obstructions can block the path of the satellite beam, and impair or eliminate coverage. In addition, the link budget of the satellite signal does not leave sufficient margin to allow reliable indoor coverage. So terrestrial transmitters can be employed to fill in the gaps, and provide indoor coverage.

One of the biggest challenges for any SFN is differential delay of transmitted signals. With OFDM, it is necessary that the delay in arrival of any two (or more) signals is less than the length of the guard interval. With just a terrestrial network, this involves setting the delays of each radiator so that coverage is optimized (i.e. signals arrive at the receiver at approximately the same time, at a majority of the target receivers). This is complicated by receivers in motion, which creates the Doppler effect. This causes the signals to vary in frequency and thus delay. Mobile media systems are designed with the appropriate carrier spacing, guard interval length, etc, to allow the best tradeoff of throughput, cell size, and vehicular speed.

When a satellite is introduced to a SFN, the situation is further complicated. A satellite's position with respect to earth is not static, but changing all the time. This is like having a terrestrial SFN with one of the towers moving all the time! Not only does this cause a differential delay, it also causes a Doppler frequency shift. All of this is added to the motion of the receiver.

To compensate for the satellite motion, or "wobble", we first have to measure it. This is accomplished by receiving the downlinked signal at the headend, much like a consumer receiver would. By knowing the time it takes to make the round trip from earth to satellite and back again, the position of the satellite with respect to the ground can be calculated. Then, the "wobble" can be derived by measuring the Doppler shift. Note that it becomes easier to measure this shift with higher carrier frequencies, since the frequency shift relative to the carrier is larger.

Once the satellite position is calculated, a satellite positioning packet is generated, which is then fed to all of the terrestrial repeaters, so that they can follow in step with the satellite. In effect, from the earlier analogy of one tower moving all the time, we are now moving all of the towers, all of the time in lockstep with all of the others. Synchronization is achieved!

LOCAL AND REGIONAL CONTENT

Another interesting aspect of satellite/terrestrial network design is how to manage local and regional programs. In many cases, a network operator may want to deliver a number of regional or national programs to all subscribers, but may want to tailor additional local programming to those communities that it is designed to appeal to. Since satellite bandwidth capacity is preciously finite, since only certain areas will need to receive the local content, and since the satellite signals must match the terrestrial signals on the corresponding frequencies, it makes sense that the local programs are not delivered over the direct-to-handset satellite link. Instead, a better solution would be to deliver the local programs *only* via the terrestrial repeaters, but since the regional/national programs must be in a SFN with the satellite, the local programs must be provided on separate channels. Note that all of the terrestrial repeaters may be in a SFN with other terrestrial repeaters, but only the regional/national channels of those terrestrial repeaters will be in a SFN with the satellite. Also, since local programs differ in content from one locality to another, local programs that share the same channel from one locality to another will *not* by synchronized, i.e., not a SFN.

SUMMARY

Mobile Media systems using a combination of satellite and terrestrial networks can provide a very cost-effective architecture, as long as satellite space corresponding terrestrial channels are available. The satellite footprint provides a good solution for wide area coverage, especially in low density populations where the cost of terrestrial repeaters would be prohibitive. Then, where satellites fall short, in urban and indoor environments, terrestrial repeaters complete the coverage picture. New technologies that incorporate single frequency networks, along with the ability to synchronize the satellite and terrestrial signals, are now available, and are being proved in trials and deployments today.

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