Satellite Radio

Zeroes and Ones – From Heavens to Home

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Satellites have been a highly effective platform for multiform broadcasts. This has led to a revival of the radio era. The satellite radio is a natural choice to bridge the digital gap. It has several novel features like selective addressing and error control. The value-added services from such systems are of particular interest.

Introduction

Man has always been fascinated by the 'heavenly voices' from the skies. This fascination has manifested itself in many mythologies where he has received divine messages, warnings, and forecasts from the heavens. It was this undiminished fascination that kept him working towards the radio system. It was one hundred years ago that Marconi first transmitted the letter 'S' across the Atlantic Ocean. At that time, conveying information across such large distances was not as much a novelty as the new concept of broadcasting. While telegraphy was constrained by physical network of lines, radio reached a widespread, unidentified audience.

With the evolution of technology, today, man-made satellites placed up in the skies are able to deliver not just messages but crystal-clear music and news directly to the listeners separated by huge geographical distances. The reception of these programmes on ground is possible using special satellite signal receivers.

Keywords
Digital radio, satellite broadcasting.

Confluence of Technologies: It is interesting to note that direct-to-home satellite television was introduced much ahead of satellite radio. This despite the fact that the television signal transmission demands more resources than radio.

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Radio is perceived to be an individual's possession because of its portability. It can be used even while one is moving. To do this from a satellite has been a major technological challenge. This has now been met by a true confluence of technologies – rocketry, satellites, computing, compression, modulation, encryption and satellite receivers.

New Demands: The demands on satellite radio are many. Besides mobility the other demands on the radio system are a diversity of formats, languages, genre, and a universal reach that cannot be met by terrestrial systems. For example, one may want to listen to a live classical concert of three hours duration without commercial breaks. A global traveller may want to hear his favourite channel irrespective of where he is located including remote and thinly-populated areas where a terrestrial choice is absent.

Satellite Orbits

A satellite's orbit is decided depending on the application. The geo-stationary orbit (GSO) is considered ideal for broadcast purposes. It is advantageous because of the ease of tracking – or rather the lack of tracking. In GSO, even though a satellite moves at a speed of over 10,000 km per hour, it appears to hang perfectly motionless in the sky. This is because for an Earth based observer, its absolute motion is annulled by the rotation of the Earth about its axis. In a GSO, therefore, the period of the satellite is one day. The unique relationship between the period of a satellite and the size of its orbit dictates that the satellite is placed at about 36,000 km over the equator with the correct magnitude and direction of velocity. (See *Box* 1.)

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GSO satellites are used for point-to-point communications as well as for point-to-multipoint broadcasting. In the latter case, the signals to be broadcast are sent to a satellite from an uplink station. These signals returned by the satellite to the Earth (downlink signal) can be received at any location falling within the footprint of the satellite transmit antenna.

Box 1. Orbital Elements

Satellite motion can be described reasonably well by considering just the gravitational attraction between the Earth and the satellite. Under this two-body approximation, the satellite obeys a second order ordinary differential equation for the position vector **r**:

$$d^2\mathbf{r}/dt^2 = (-\mu/r^3)\mathbf{r},$$

where μ is a constant.

To solve this equation, we need to specify initial position and velocity vectors. Instead of these six scalars, it is possible to define an equivalent set of six Keplerian orbital elements that are physically descriptive of the orbit. Based on this description, the GSO will have semi-major axis (a) of 42164 km, eccentricity (e) of zero, inclination (i) of zero, two other parameters (Ω and ω) not defined and the sixth parameter varying uniformly from 0 to 360 degrees.

Modulation

Modulation is the way information is imparted to the electromagnetic signal that is referred to as the carrier wave. In amplitude modulation (AM), the amplitude of the radio frequency (RF) carrier is made to vary in accordance with the audio waveform. It is obvious that in this mode, it would be quite sensitive to additive electrical noise. Frequency modulation FM has a much better noise immunity, as it is the frequency of the carrier wave that is varied in a small range according to the audio waveform. However, noise free reception does not necessarily mean high fidelity (HiFi). HiFi refers to reproduction of all the frequency components correctly at the receiving end. In digital modulations one uses perceptual coding using auditory masking. This means the retention of only those components that the human ear can perceive. In this scheme, the human ear acts as a measuring instrument instead of traditional measures like signal to noise ratio (SNR).

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The AM carrier frequencies can cover several thousand kilometres. The frequencies used for FM and satellites are such that the propagation is direct line of sight. Hence, the path between the transmitter and the receiver site must be substantially unobstructed. The bigger FM stations mount their trans-

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mitters on a tower of a few 100 metres high, covering radius of several tens of kilometres. GSO is like an invisible tower of height 36000 km and hence the line of sight of a single satellite extends to cover about 40% of the surface of the Earth. However it must be noted that the signal strength from the satellite is much weaker as it follows inverse square law. The weakness of the signal explains why a satellite receiver, in general, is more expensive than a terrestrial FM receiver.

For moving customers in urban environment, it is possible that there are obstructions like tunnels or high rise buildings and in order to have continuous service, it is necessary to have ground-based repeater network using what is known as multi-carrier modulation (MCM) techniques.

Digital Radio

Because of the tremendous advancement in digital technology in the recent years satellite radio is fully digital. In a digital radio, the transmitter processes sounds into patterns of binary digits and at the listening end, the digital radio reproduces the sound from the digits. By using techniques of *forward error control*, it is possible to make the reception virtually immune to interference.

Besides satellite radio, digital broadcasting can be totally ground-based as in the case of Eureka 147 that operates in L-band. Digital broadcasting can be done through the existing AM or FM band so as to use the existing stations and to receive the digital signal in the same analog dial position. This scheme is called 'in band on channel' (IBOC).

The transition to digital produces a number of other benefits too. It is possible to adopt encryption technology so that the programs can be delivered to whom it is intended. In the case of a satellite-based digital signal broadcast, it is possible to provide error control processing on the satellite to correct for errors in the transmission, thereby simplifying and downsizing the ground terminals.

Digital Compression

In broadcasting terms, bandwidth is the 'space' required to deliver a given signal. For example, current TV signals require as large as 30 MHz per channel, FM radio requires 0.2 MHz and AM radio needs only about 0.01 MHz. By conventional conversion from analog to digital stereo sound will require about 1.5 million bits per second that is indicative of a bandwidth of 1.5 MHz. By adopting advanced audio compression techniques, the bandwidth can be reduced by a factor 10-20. This is made possible by using perceptive coding that takes into account the characteristics of the human ear. It is the same technology that drastically reduced the storage and transmission requirements of music on computers. In the WAV format, a three-minute song will take about 30 megabytes of disk space and could take more than three hours to download on an average modem. In the case of MP3, 14 hours of music can fit into a single CD (*Box* 2).

Box 2. MPEG (Motion Pictures Experts Group) Summary

MPEG-1 provides for sampling rates of 32, 44.1 and 48 kHz at bit rates from 32 to 448 kbps.

MPEG-2 is a low sampling extension of MPEG-1 and provides additional sampling rates of 16, 22.05 and 24 kHz.

Independent of this choice there are three coding algorithms called Layer 1, 2 and 3, each tailored for a particular application. Layer 3 has the highest encoder complexity, the largest delay and the highest coding efficiency.

Frequency Allocation and Regulation

For the coexistence and mutual non-interference of various services elaborate schemes have been evolved under the auspices of the International Telecommunication Union (ITU). ITU allocates frequencies for various services.

As the satellite is located well above the ionosphere, the radio frequency of the carrier will have to exceed the ionospheric plasma frequency that is typically a few tens of MHz. For digital audio broadcast (DAB), a segment in L-band (1452-1492 MHz) is allocated in most of the regions except in USA and Canada where this service is available in S-band. (See *Box* 3.)

The Present Scenario

Satellites for Radio Networking: Even though satellite radio is relatively a new phenomenon, satellites have been used to network the radio stations for a long time now. For example, All India Radio has been using INSAT for over fifteen years to carry network newscasts and syndicated programs. However these

Box 3. Comparison of Different Radio Schemes

Scheme	Carrier Freq. Range (MHz)	Bandwidth (kHz)	Typical Audio Range (Hz)
AM	0.525-1.7	10	50-5000
FM	88-108	0.2	50-15000
Satellite	L band and S band	Not applicable	High fidelity

programs are not meant for the end user but are for rebroadcast via terrestrial transmitters.

Satellites in orbit: With the launch of Afristar in 1998 and Asiastar in 2000, WorldSpace offers audio and multi-media broadcasts to the most-populous and under-served regions of the world. Very recently, Sirius radio and XM radio are offering a choice of more than hundred channels including music formats, news, talk shows and entertainment programming to mobile customers in the US. For the first time the concept of subscription based radio has been introduced in these systems.

Value Added Services

In addition to a variety of crystal-clear music programs, any digital radio can easily be configured to display information such as song titles, traffic information, weather data, stock-market quotations, etc. It has tremendous potential for being used in distance education, telemedicine and other off-beat applications. For example, WorldSpace satellites offer a unique mode of synchronous, instructor-led training by exploiting the feature of multiple service components in the same broadcast channel. It is also possible to download pre-fixed websites directly onto the user PC without an Internet connection or a telephone line. This will be an important factor in bringing 'infotainment' to such regions where Internet is either unavailable or is too expensive.

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Suggested Reading

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