

Seeking spectrum – for new forms

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One of the fundamental limitations of any business is the availability of basic resources.

Telecommunications is no different. After years of having more bandwidth available than could be used, we find ourselves facing a potential shortfall in capacity. The new bandwidth-hungry Internet, multimedia and high-definition video demands are coming. These could exhaust both traditional terrestrial and satellite resources. Let's look at some of these new requirements (services not previously offered) and how they and, in a much larger sense, expanding existing services can find the spectrum and spatial resources needed in the near future.

I will concentrate on two emerging services and an older service that is likely to see a sizeable expansion. These are typical of other emerging opportunities.

S-DARS

The quantity, quality and variety of terrestrial radio programs varies as a driver moves across the countryside. The Satellite Digital Audio Radio Service (S-DARS) represents the opening of a new market for satellite operators, programmers, radio manufacturers, and automobile dealers. This has the earmarks of a consumer mass-market entrant provided the quality of service can be fulfilled. The innovative uses of multiple geostationary or highly ellip-

tical satellites and time-staggered transmissions are intended to overcome the problems of buildings and objects getting between the vehicle and one of the satellite paths. In urban areas, terrestrial repeaters will be added to overcome the blockage in the city canyons formed by buildings.

Unfortunately, there are two frequency bands allocated, one to the United States and India (at S-band) and a second to the rest of the world (at L-band). At least the two US systems are working to make any receiver function with either S-DARS system. The hardest part will be constructing a high-technology, highly sensitive receiver. The receiver will need to receive signals from two satellites plus one or more terrestrial repeaters. It then must be able to reassemble a continuous audio bit stream from the best pieces from each of these signal paths. This needs to be done in the face of multipath reflections into a quasi-omnidirectional antenna. And it needs to be done inexpensively and reliably.

LOCALIZED TELEVISION

In many nations the television network(s) are government-owned and consist mainly of repeaters relaying the capital's view. In other nations, local news, weather, and programming are inserted into the schedule by the individual broadcasters. Independent stations assemble their own

program schedules from tapes, movies or syndicated satellite feeds. In the United States there are pressures to provide local TV stations via satellite, just as they are provided by local cable TV systems. The rural communities feel they are being left behind in the provision of big city TV stations and Internet services via satellite. The number of subscribers per kilometer in these rural areas is too low to justify even a simple coaxial cable TV system. Political pressures are growing to force a solution to these rural needs. A US\$1bn loan guarantee is about to be signed by the US government and several satellite approaches are emerging.

The primary design challenges of localized TV provision are:

- To provide sufficient radiated satellite power (EIRP) to provide video into small (45cm) antennas
- To find sufficient spectrum to handle 1000-plus analog TV stations, each of which may be converted, during the life of the satellite system, to digital TV with at least four TV programs each.

One efficient way to meet both requirements is to use spot beams.

MARKET ENTRY

The dictates of the World Trade Organization on the opening of national markets to non-national entrants cut both ways. Basically, if systems from nation A can serve nation Z, then systems

of satellite telecommunications

from Z can be offered in A. There are some limitations, but generally these are not barriers to entry, at least in developed nations. It is in these very nations that the major telecomms markets exist and therefore are the most tempting to outsiders and startups.

Natural limitations may emerge as a greater barrier to entry than the regulators. A global shortage of orbital slots and spectrum, especially covering the developed nations, is now becoming evident. These lead to the next two topics, frequencies and orbits.

SPECTRUM CHOICES

The traditional spectrum choices are the C- and Ku-bands. Each has seen some modest expansion in recent years. Unfortunately, the added spectrum is not really usable in all nations due to pre-existing terrestrial services that need to be protected. As a result, most or all of the desirable C- and Ku-band slots covering Europe, Asia

and North America are in use or will be in a few years.

There are alternative frequency bands that are emerging. Some of these have already been used for government services. Only the bands with over 500 MHz of spectrum will be considered. The lowest of the alternative bands is called X-band and has a pair of 500 MHz segments for uplinks and downlinks at 8/7 GHz (the first number is the nominal uplink frequency and the second is the downlink). This is very attractive in a commercial sense as the links are slightly higher in frequency than the C-band hardware while being much less sensitive to rain attenuation than the Ku-band. It has been proposed to use this as a high-power direct-to-home TV service band.

There are several limitations:

- The X-band is limited to government (military) satellite systems in many nations (Japan, NATO, US, Russia, etc).

- The existing satellites have sensitive uplinks and wide area (limited power) downlinks. A DTH system would have powerful uplinks and downlinks, thus the stage is set for a difficult coordination.

- The modulation methods used in government satellites and their traffic probably are classified. If CDMA is used, the traffic will probably be invisible and thus hard to avoid. Verification of claims of interference may be impossible. This will make coordination and solutions very difficult.

- The high end of the downlink band is only 160 MHz away from the low end of the uplink band. Even a slight out-of-band emission from a satellite power amplifier could get into the satellite's receiver and cause feedback (self-jamming). Considering a typical transponder gain of 100 dB, standard filters will not be enough.

- Finally there may be an unknown inventory of X-band radars and other military equipment in the

band that could jam the direct-to-home receivers.

Skipping over the increasingly popular Ku-band, the next higher band is Ka (30/20 GHz). Depending on the registering nation there is 500 to 3500 MHz available in each direction. Applications, especially for small office/home office uses, are emerging. The biggest challenge is the need to make the Earth station terminals small, reliable and inexpensive. Many of the Ka-band systems use large clusters of small spot beams. EuroSkyWay, for example, has 32 spot beams. The spot beams increase the power on the ground and decrease the uplink power requirements. Both drive the user terminal costs down. At the same time parts of the spectrum can be reused in separated beams. This multiplies the available spectrum.

Still higher in frequency is the V-band (or Q-band) at 50/40 GHz. Three to five GHz of spectrum are available. Fourteen US and non-US applicants filed for 17 types of satellite systems using low to geostationary orbit plans. Recent studies using the concept of 'net loss', suggest that for certain latitude and rain conditions, a 44 GHz may be optimum for a hybrid HEO/GEO system. 'Net loss' is the aperture gain of a fixed-size antenna minus the rain loss. Much remains to be done in these bands before they are ready for commercial use.

Table 1 Commercial satellite communications service frequencies

Band	Uplink GHz	Downlink GHz	Applications
V or Q	50	40	High speed two-way data
Ka	30	20	High speed two-way data & TV
Ku (BSS)	17	12	Direct to home video
Ku	14	11-12	VSAT, video & Internet
X	8	7	Government traffic
C	6	4	Video, voice & data
S	2	2	Mobile voice services
L	1	1	Mobile voice services

Typical frequencies, actual systems have some variation in assignments.

Note: These band designations are as used by the commercial operators.

Non-commercial users may have different frequency range definitions.

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MAXIMIZING CURRENT RESOURCES

An alternative to new spectrum is the better use of existing bands. One potential method is to reverse the directional sense. In this case and uplink (eg 14 GHz for Ku-band) becomes a downlink and the downlink and uplink functions are interchanged at 11 to 12 GHz. With care this can be accomplished, thus theoretically doubling the existing spectrum. The regular and reverse frequencies should not be carried on the same satellite due to the high probability of feedback. Satellites and Earth stations can be physically separated. Reverse frequency plans may not be for every application, especially those with omnidirectional antennas, but other applications can be managed. As always, interference must be carefully considered. There are some current reverse frequency uses; for example, the Globalstar telemetry and feeder downlinks at 7.0 GHz are the uplink bands for other satellites.

ORBITS

Frequency reuse can also be accomplished through spatial sharing. The pioneer in this technique is SkyBridge. This is a low Earth orbit (LEO)

system that proposes to share the Ku-band spectrum with geostationary satellites by shutting down its transmissions and reception whenever one of its satellites is near the geostationary arc. Considering that the GEO arc only occupies a tiny percentage of the 6.283 steradians in a hemisphere, this method allows, for the first time, the efficient use of the vast remaining sky area. Most LEO systems, however, are not as adventuresome. Perhaps they await the results of the latest WRC meeting in Turkey, which is still in session as this is being written.

Low Earth orbits require many tens of satellites and thus tend to be expensive. They also need most or all of the constellation to be in place before service revenues can start to flow.

A single geostationary (GEO or GSO) orbit satellite is all that is generally needed to start service. These satellites tend to be large and expensive, but the system cost may be lower than a LEO constellation. Once these satellites have been launched and checked out in orbit, they tend to have long and very profitable lives.

Somewhere in between the LEO and GEO is the MEO, the medium Earth orbit satellite. A smaller (than LEO) constellation is needed with a

dozen satellites being typical. Some claim this is a minimum cost solution for global coverage; time will tell. Unlike GEOs, a tracking antenna capability is needed on the MEO satellite and at the MEO Earth station, thus adding cost, complexity and maintenance issues. The MEO satellite motion across the sky is slower than a LEO. There is no apparent motion for a geostationary satellite.

Another attempt to improve on the GEO orbit is the highly elliptical Earth orbit (HEO). This also goes under the names of 'Molniya' and 'QuasiGEO'. Molniya is the name of a long series of Russian satellites used to provide Russian and polar coverage. Most of Russia and the CIS are at high northern latitudes, which are poorly (or not at all) served by an equatorial GEO system. The Molniya orbit is elliptical with the high point (apogee) in the northern hemisphere and the low point (perigee) in the southern.

Like a child in a swing, when the satellite reaches the high point it appears to pause briefly before plunging back towards its low point. In reality, the satellite coverage of countries in the northern hemisphere lasts for hours with a high elevation angle. Apparent motion (as seen by an Earth station) is limited,

thus allowing consideration of small, fixed pointing antennas. At least three satellites are needed. Variations from the basic Molniya orbit are used to optimize the coverage of certain areas (such as Europe or northern Asia).

INTER-SATELLITE LINKS

ISLs are another way to stretch the present resources and to allow new services. An international link may involve several satellites and Earth stations, each with its link and use of spectrum. Some video from an European uplink hops the Atlantic to a north American Earth station, to a domestic satellite to another Earth station, thence into a Pacific satellite to the Japanese downlink station. ISLs between the Atlantic and Pacific satellites can eliminate two spectrum and one satellite use. It also shortens the latency. The ISL frequencies were selected because they are useless for space to/from ground use due to water vapor absorption. This aspect also isolates the ISL links from interference from terrestrial services.

ISLs have been deployed in government satellites and most recently in Iridium. Since Motorola has never publicly released information on where it ran into technical difficulties it is impossible to tell what, if any, role its long and elaborate chain of ISLs played in its demise. Practical systems will be much simpler. **SBI**

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