

Intersatellite links

Tested idea to new technology

During my career as a telecommunications consultant, at least half a dozen client organizations have shown interest in putting intersatellite links into their spacecraft. For each of the types of service offered by these client organizations there was clearly potential for such links. However, each and every time the perceived risk of being a pioneer in the field outweighed the expected benefits. Now this is changing and several commercial satellite systems incorporating ISLs are filed with the FCC and ITU. In the very near future such intersatellite links (ISLs) offer expanded capabilities and extended reach to commercial satellite systems. Here I will examine the following considerations: why ISLs will be used; how they work; and, today's ISL technology.

Terrestrial fiber optic cable is a tested technology used to create high-quality communications networks on the surface of the Earth. Similarly, ISLs are a tested technology, in limited use since the 1976 launch of LES-8 and 9, bringing together parts of distributed satellite systems into high-quality networks (see Table 1).

Function and application

With the rapid growth in LEO and MEO communications satellite constellations, intersatellite links are likely to perform multiple functions:

- providing originator - destination shortest-route connection
- selecting lowest cost terres-

trial routing

- by-passing of local and international carriers
- by-passing busy satellites and terrestrial gateways (packet switching)
- improving spare transponder capacity utilization
- allowing use of less-than-optimum GEO slots

In situations where geographically large countries or regions cannot obtain uniform, high-elevation coverage from a single satellite in a less than ideal orbital slot, as few as two ISL-linked (and differently positioned) GEO craft can become a virtual single satellite (see Figure 1). Multiple interconnected satellites permit the use of smaller, higher gain spot-beams, while continuing to maintain good elevation angles.

The extension of regional satellite system coverage into adjacent or very distant areas is also possible through ISLs. Most significantly this involves reduced spectrum demand and reduced latency, the latter being particularly important for time-critical relays of news (SNG), financial information and the updating of Internet caches (sites offering local access to www data based in geographically distant computers).

Non-ISL Europe-Asia transmissions require three satellite 'hops', that is three uplinks and three downlinks:

- European Earth station - Trans-Atlantic satellite - Eastern USA Earth station
- Eastern USA Earth station - US domestic satellite - Western

USA Earth station

- Western USA Earth station - Trans-Pacific satellite - Asian Earth station

Alternatively, an ISL between two craft requires only one up and one downlink, a three-to-one reduction in spectrum demand, together with reduced transmission delays and transponder/Earth station costs. A single uplink to a satellite with global ISL links creates a virtual global satellite.

The NASA Tracking & Data Relay Satellite System (TDRSS) is one of the most widely known applications of ISLs. It retrieves data from LEO weather and Earth resources satellites, the Shuttle and the International Space Station for instantaneous analysis and provides a link into these LEO satellites for command and control via a GEO TDRS satellite.

LEO-GEO 'chat'

So far, almost all of the commercial applications of ISLs have been GEO-GEO or LEO-LEO. There is no reason why there cannot be LEO-GEO links, beyond the NASA TDRS System - which is not dedicated to communications purposes - to combine the best attributes of each orbit type (see Figure 2).

The Communications Center expects that ISLs will be the thread that ties various system parts together. Some of these parts (in LEO, MEO, high orbit or GEO, including regional GEO systems) will be acquired through commercial mergers or consolidations. Undoubtedly, ISL capability will make a satel- ➔



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lite system more attractive to its users and financiers. The services they will be able to offer to the consumer end of the market will be characterised by higher speed, better quality and lower costs.

ISL compatibility between different systems is not necessarily guaranteed, e.g., different frequencies, but is easily effected using a simple translation satellite to receive, re-format and re-transmit data in each direction between the systems.

Fixed and movable systems

Some ISLs (e.g., as applied in the TDRSS) use movable antennas; these are primarily used for interconnections between GEO and LEO satellites, though applications between GEO craft may involve some degree of tracking too. The best examples of this are the 14° inclined geosynchronous orbit Lincoln experimental satellites LES-8

and LES-9, which are separated by 10° of orbit arc. A Ka-band ISL utilizes tracking antennas to maintain the link with the other of the pair as it moves through its figure eight track.

More common are non-movable applications for ISLs, e.g., the US government's Milstar (GEO-GEO) and the commercial GMPCS Iridium system (LEO-LEO).

An, as yet, untested application is a link between satellites and a high-altitude repeater (plane or balloon) in the atmosphere, though this does not constitute a true ISL.

Not surprisingly, there are tradeoffs between tracking and fixed ISL systems:

- Tracking - satellite station-keeping requirements can be relaxed as the movable components allow some flexibility
- Fixed - satellites within the orbit plane (and, in the case of non-GEOs, adjacent or cross-plane satellites) all need to

remain within the tight beamwidth of the ISL

However, in some applications such as large constellations, other station-keeping requirements may be as stringent as those for the ISL.

Useless frequencies go to work

As shown in Figure 3, all 12 of the US Ka-band systems have been registered by the USA in six bands. Globally there is an apparent preference for the 60 GHz and 125 GHz bands.

Will the development of the technology for these radio frequency ISLs be the key to the back door that opens the Ka- and V-bands?

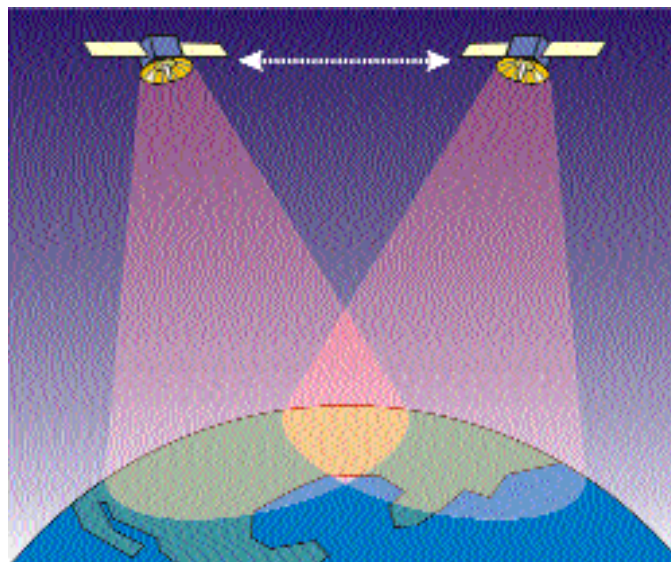
ISL bands tend to be centered on the water vapour and oxygen absorption bands of the atmosphere. 60 GHz signals, for example, are useless for satellite-Earth communications because they are absorbed long before reaching the surface: at this frequency the minimum atmospheric attenuation (space-Earth) is 100 dB in addition to normal path loss. Severe levels of atmospheric attenuation occur in the terrestrial-orbit direction too. Even LEO satellites benefit from this isolation from the Earth's surface.

Quite naturally, the Earth also limits the length of the path between GEO craft, blocking it if the satellites are separated by more than 162.6° of longitude.

Typical ISL parameters are:

- Radio frequency bandwidths: 300 - 1000 MHz

Figure 1. Use of the ends of the orbit arc



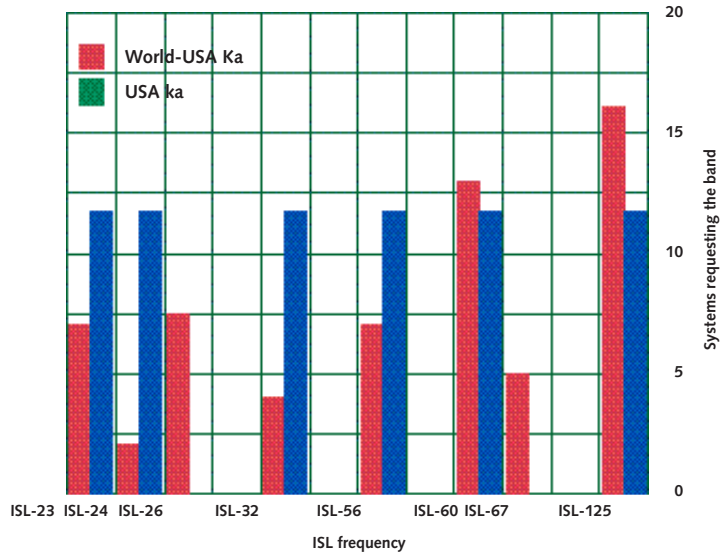


Figure 3. ISL RF requests (systems, not satellites)

- Antenna beams: 0.25° or 4.4 milliradians
- Power link (bandwidth and distance² dependent)
- Power amplifier values: 20 - 200W

Optical ISLs

Not yet subject to ITU or FCC regulation are ISLs using laser wavelengths (see Table 3): optical telescopes instead of antennas, lasers as transmitters and Charge Coupled Devices (CCDs) as receivers. Ideal for high data-rate applications, the high focusing gain of laser beams produces the optical equivalent of a high radio frequency EIRP (Effective Isotropic Radiated Power). Of course, the narrow laser beam must be pointed very precisely, requiring still more exacting station-keeping, greater platform rigidity, reduced vibration and/or precision tracking telescopes. As with radio frequency ISLs, high gain receiving equipment must be shielded from solar noise interference and any solar reflections that could burn out the optical detectors.

The Silex - Semiconductor Intersatellite Link Experiment - program (with Matra Marconi as prime contractor under the European and French space

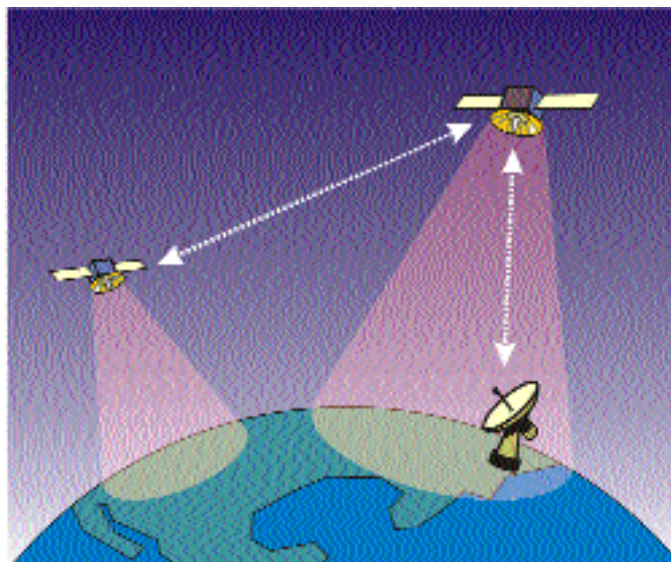
agencies) put in orbit March 1998 aboard the SPOT4 remote sensing satellite uses Aluminum Gallium Arsenide [AlGaAs] as a semiconductor. It will enable real-time transmission of SPOT4 images to Earth stations via the Artemis satellite to be launched in 2000. In addition, the Japanese will have access to 40% of the capacity of Artemis to operate with their OICETS (Optical Interorbit Communications Engineering Test Satellite) project which is designed to demonstrate optical ISLs in LEOs and to prove the inter-

operability of optical intersatellite terminals designed by different manufacturers. Other test-bed applications are planned into the next century. **SBI**

Editor's note: The 1998, Quarter 3 issue of SBI featured an item about the United Arab Emirates CERT/Swiss Contraves Space SLACE (Satellite Laser Communications Experiment) project to be carried aboard the ESA free-flying retrievable carrier, Eureka, in 2000.

Optical or laser wavelengths are attractive for high data rates

Figure 2. LEO-GEO intersatellite links



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I have been approached at least half a dozen times by clients interested in putting ISLs into their satellites

Table 1 ISL systems in operation

Satellite system	ISL Frequencies	Launch	Uses
LES-8 & LES-9	36 to 38 GHz	1976	Department of Defence & MIT Bit rates: 10 kbps or 100 kbps
TDRS 1 to 6	2.0, 13.8 & 15 GHz	1983-93	Data collection and relay
Iridium	23 GHz	1997-?	LEO MSS (ISL at 7 Mbps)
ETS-6	2.0, 2.3, 23 & 32 GHz Laser	1994	Launch failure
ETS-7	2.0, 13.8 & 15 GHz	1997	ISL to TDRS & sub satellite
COMETS	2	1998	Limited by launch failure
ADEOS	23 & 25 GHz	1998	Limited by launch failure
Globalstar	59 GHz	1998	LEO MSS
Russian	Unknown	????	Probably military, no data available

Table 2 The choice of satellite-to-satellite frequencies

Frequency (GHz)	Bandwidth (MHz)	ITU Status	Code	Notes
22.55 – 23.55	1000	Co-primary	ISL-23	Radio astronomy caution
24.45 – 24.75	300	Co-primary	ISL-24	
25.25 – 27.5	2250	Co-primary	ISL-25	Geostationary uses limited
32 – 33	1000	Co-primary	ISL-32	Also used for radio navigation and deep space (32 to 32.3 GHz)
54.25 – 58.2	3950	Co-primary	ISL-56	
59 – 64	5000	Co-primary	ISL-60	
65 – 71	6000		ISL-67	
116 – 134	18000	Co-primary	ISL-125	
170 – 182	12000	Co-primary		
185 – 190	5000	Co-primary		

Caution: All bands are shared with other services

Table 3 Optical wavelengths for ISLs

Laser Source	Wavelength (micrometers)
Diode pumped Nd:YAG (YAG)	1.064 – 0.503
Indium Gallium Arsenide Phosphide (InGaAsP)	1.3 – 1.5
Aluminum Gallium Arsenide (AlGaAs)	0.8