Topic	Seismic data transmission links used in seismology in brief
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The following issues are discussed:

- cost of data transmission equipment and its installation;
- cost of operation of data transmission lines,;
- required maintaining of the data transmission links;
- data throughput;
- reliability of data transmission;
- continuous versus event file data transmission capability;
- applicability in respect to high/low seismicity regions and strong/weak motion networks;
- remote seismic station-to-recording center distance capability;
- robustness against strong earthquakes; and
- special issues.

Type of links	Description
Wire lines	▪ inexpensive establishment if not too long ▪ inexpensive operation ▪ little in-house maintenance ▪ relatively high throughput with modern modems ▪ high reliability of data transmission links ▪ continuous and event file data transmission possible ▪ appropriate for high and low seismicity regions and weak and strong motion seismology ▪ useful for very short distances only (a few km maximum) ▪ robust against damaging earthquakes
Leased phone lines	▪ inexpensive establishment (unless high installation taxes required) ▪ very expensive operation in the long-run, operation cost usually proportional to the total length of the lines ▪ no in-house maintenance ▪ relatively high throughput with modern modems ▪ reliable data transmission ▪ capability to transmit data continuously but less efficient in event files ▪ appropriate for high and low seismicity regions and weak motion networks, rarely used in strong motion networks ▪ appropriate for short and long distances ▪ medium robust against damaging earthquakes
Dial-up phone lines	▪ inexpensive establishment ▪ medium expensive operation, cost of data transmission is proportional to the amount of data transmitted, that is to the seismicity in the region ▪ no in-house maintenance ▪ usually low effective throughput despite of modern high-throughput modems

	▪ medium data transmission reliability ▪ only event file data transmission feasible ▪ applicable for strong motion networks and weak motion networks but in low seismicity regions only ▪ applicable from short to very long distances ▪ not robust against damaging earthquakes, temporarily fail to work after stronger earthquakes with macroseismic effects due to overloading or even break-down of public phone system (exceptions are seismic systems with several input phone lines and with the remote equipment which grabs the lines automatically at the moment of triggering to large events) ▪ reliability of data transmission highly depends on the overall quality of public phone systems in a country; in many developing countries this is a serious obstacle for dial-up phone line systems ▪ incapable of serving alarm and civil defense purposes
Radio-frequency links on VHF or UHF RF band	▪ medium expensive establishment ▪ inexpensive operation ▪ require in-house maintenance ▪ moderate but mostly sufficient throughput for digital data transmission on standard 3.5 kHz bandwidth 'voice' channels ▪ medium reliable ▪ continuous and event data transmission possible ▪ applicable for high and low seismicity regions ▪ used mostly in weak motion networks, rarely used in strong motion applications ▪ applicable for distances up to 150 km (100 miles) with direct point-to-point connection and about three times that much using repeaters ▪ robust to strong damaging events ▪ have limited low-dynamic-range of data acquisition for analog FM telemetry ▪ free frequencies are often difficult to obtain ▪ frequently subject to RF interference in developing countries ▪ RF survey required
RF spread spectrum links	▪ medium expensive establishment ▪ inexpensive operation ▪ require in-house maintenance ▪ medium high data throughput ▪ medium reliability of data transmission ▪ continuous and event file data transmission possible ▪ useful in high and low seismicity regions and for weak and strong motion networks ▪ useful for relative short point to point distances from 20 to 100 km maximum ▪ robust to damaging earthquakes ▪ insensitive to RF interference; implies the reduction of multi-path effects compared to VHF and UHF telemetry ▪ permission to operate is easy to obtain or not required at all ▪ maximum point-to-point distances depend on regulations limiting the maximum transmitter output power in a particular country ▪ RF survey required
Microwave RF links	▪ expensive establishment ▪ expensive operation ▪ maintaining usually beyond the scope of seismological institutions ▪ high throughput ▪ high reliability

	▪ continuous and event file data transmission possible ▪ used in high and low seismicity regions and weak motion networks ▪ appropriate for long distances ▪ medium robust against earthquakes ▪ usually these lines are hired from a second party communication company they are often a part of public phone system in the country
Computer networks	▪ medium expensive establishment (if connection points readily available) ▪ medium expensive operation ▪ no in-house maintenance ▪ high data throughput ▪ reliable ▪ semi-continuous and event file data transmission possible ▪ used in high and low seismicity regions and strong and weak motion networks ▪ convenient for medium to very long (even global) distances ▪ allow reduced ownership cost ▪ allow 'portable' central recording site anywhere in the network ▪ frequently unavailable computer 'tabs' at remote seismic station sites (so called ‘last mile problem’) ▪ different protocols can be used, Internet with TCP/IP protocol is increasingly gaining popularity
Satellite links	▪ very expensive establishment ▪ expensive operation ▪ maintaining usually above the scope of most seismological institutions ▪ high data throughput ▪ reliable ▪ continuous and event file data transmission possible ▪ appropriate for high and low seismicity regions and weak and strong motion networks ▪ medium to very large distances can be covered ▪ robust to damaging earthquakes ▪ convenient for extremely remote sites and large regional and national seismic networks ▪ rarely used at present due to high cost, however satellite data transmission cost is constantly decreasing ▪ for shared satellite hubs additional links from the hub to the seismological center required ▪ high cost of the hub in systems with ‘private’ local hub ▪ high power consumption of remote stations poses problem to solar panel powered stations