WHITE PAPER

How to Achieve 1Gbps Link Capacity with Microwave Links – Bare Truths and False Claims

V1.1

1. Introduction

Capacity requirement for backbone links and networks have rapidly grown in recent years so that many backhaul PTP links are specified to carry 1Gbps.

Licensed microwave links are the most natural choice for mid to long distance 1Gbps PTP links. In order to address this market, many equipment vendors claim that their PTP links can achieve 1Gbps by citing various features. The real story is of course not that simple.

This white paper presents a collection of facts that are designed to peel the vendor marketing layers and give the reader bare truths on how to achieve 1Gbps links.

2. Full Duplex vs. Half-Duplex

First, most of the microwave links operate in the full-duplex mode or frequency division duplexing (FDD), which has a separate frequency channel for each direction of traffic. 1Gbps full duplex means 1Gbps in each direction of a PTP link (total capacity of 2Gbps). In contrast, half-duplex or time division duplexing (TDD) mode, the channel is shared for both directions. So, if a TDD link is specified as 1Gbps, it means the total aggregate capacity is 1Gbps.

TDD is great for last mile access networks, but for backbone networks in licensed bands, FDD is a more practical choice. The traffic tends to be more symmetric to make better use of FDD. Plus, in most countries, the spectrum licenses are restricted to FDD links, so TDD will not be allowed in licensed bands.

3. 1+0 Link Capacity

The link capacity for a radio link is determined by channel bandwidth and modem modulation. There are a few minor factors other than these two, but they don't change things much. The following table presents data capacity (in Mbps) for a typical microwave link.

Modulation	ANSI (Balanced Mode, 1+0)				ETSI (Balanced Mode, 1+0)			
	30MHz	60MHz	80MHz	160MHz	28Mhz	40Mhz	56MHz	112MHz
QPSK	41	82	109	218	41	55	76	152
16QAM	82	163	218	436	82	109	152	305
32QAM	107	215	286	572	107	143	200	401
64QAM	133	266	355	710	133	177	249	497
128QAM	159	317	423	846	159	212	296	591
256QAM	181	362	483	966	181	241	338	676
512QAM	197	397	551	1102	197	263	371	741
1024QAM	217	438	588	1176	217	289	409	818
2048QAM	235	474	639	1278	235	313	442	885

These numbers may be called "balanced mode" with some level of coding included (in Solectek's case LDPC coding). Thus, you can enhance the capacity by reducing the coding (high throughput mode) or enhance the link budget by increasing the coding (high gain mode). However, the differences are only a few percent in each direction, so the effect due to mode change is not significant. The following is a link capacity table of high throughput mode.

Modulation	ANSI (Throughput Mode, 1+0)				ETSI (Throughput Mode, 1+0)			
	30MHz	60MHz	80MHz	160MHz	28MHz	40MHz	56MHz	112MHz
QPSK	43	86	116	232	43	57	81	161
16QAM	93	186	248	496	93	124	174	347
32QAM	118	235	314	628	118	157	220	439
64QAM	142	284	380	760	142	189	265	531
128QAM	167	335	446	892	167	223	312	625
256QAM	192	384	512	1024	192	256	356	717
512QAM	207	416	578	1156	207	276	389	777
1024QAM	226	456	613	1226	226	301	426	851
2048QAM	244	492	663	1326	244	325	459	918

Please note that the channel bandwidth is the single largest factor in the link capacity. These are determined by the authorities and you are often limited to smaller bandwidths than what radio systems are capable of today. For example, you may be able to get 80MHz in the US (ANSI). In the ETSI countries, channels are mostly limited to 28 or 56MHz, with 112MHz allowance in rare cases. Thus, link capacity possible for your deployment is not necessarily determined by the radio system, but your local authority's allowance for maximum channel bandwidth.

In addition, for longer distances, it is not possible and not advisable to use high-order modulations so that a certain link margin is maintained against rain or other fades.

4. 2+0 Link Capacity

Naturally, the 2+0 link capacity is twice of the 1+0 capacity as seen in the following table:

Modulation	ANSI (Balanced Mode, 2+0)				ETSI (Balanced Mode, 2+0)			
	30MHz	60MHz	80MHz	160MHz	28MHz	40MHz	56MHz	112MHz
QPSK	82	163	218	436	82	114	152	305
16QAM	164	326	436	872	164	129	305	609
32QAM	214	430	572	1144	214	314	401	802
64QAM	266	533	710	1420	266	380	497	995
128QAM	318	634	846	1692	318	446	591	1183
256QAM	362	725	966	1932	362	512	676	1353
512QAM	394	794	1102	2204	394	551	741	1483
1024QAM	434	876	1176	2352	434	603	818	1635
2048QAM	470	948	1278	2556	470	650	885	1770

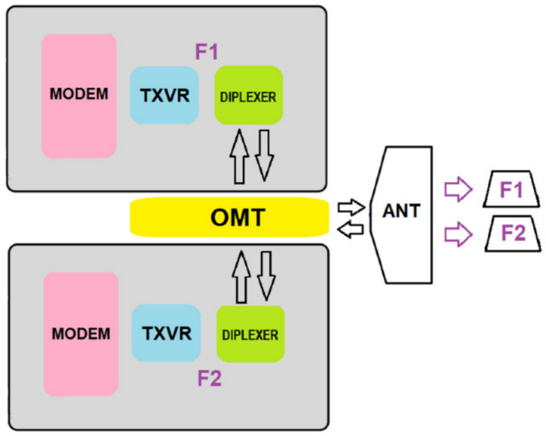
You can see that 2+0 radio systems are needed to achieve true 1Gbps capacity. For example in ANSI, you can achieve that even at 512QAM at 80MHz channels. In ETSI, you will get close at ~900Mbps using 2048QAM and 56MHz channels. You will need to use high throughput modes and/or utilize compression to get to 1Gbps. Of course, if you can obtain 112MHz licenses, then you are in the clear even at 256QAM.

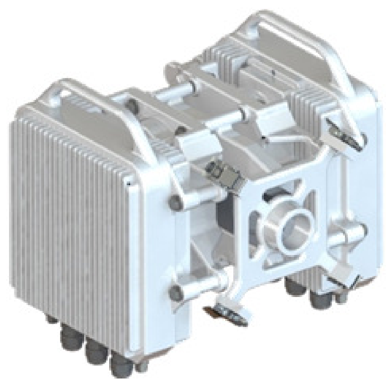
5. Two Different Ways to Implement 2+0

The following describes two ways of achieving 2+0 capacity – the first is the traditional way and the other very recent cutting-edge technique.

Traditional method – two terminal combination

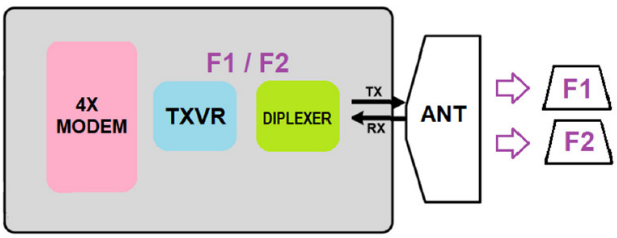
This is basically two radio terminals combined together with a combiner or orthonormal transducer (OMT) into a single antenna. Recent radio designs make it possible to put one multi-core modem with two radio chains with OMT all integrated in a single enclosure. So, the form factor does not look much different from a single radio and installation is much simpler than multiple radio terminal combinations.

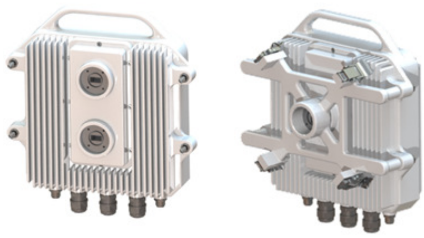




Novel method – sub channel operation

This is a cutting-edge technique to get more out of a single radio link (single transceiver). Basically, two independent data streams are launched from a multi-core modem into a single RF chains using two sets of frequency channels. The benefit is that there is no additional hardware cost for 2x capacity.





Comparison between two implementations

The sub-channel operation method does come with some limitations.

Diplexer Limit – two sets of frequency channels must fit within the radio's diplexer range. This depends on the specific case. In general, larger channel bandwidth makes it more difficult.

Regulatory Limit – frequency coordinators must ensure your use of two channels does not cause interference. Authorities may not allow spectrum licenses for two sets of channels in close ranges. Again, regulatory allowance is more difficult for larger channel bandwidth.

Distance Limit – The sub channel use requires a backoff of Tx power by 3-4 dB. This is OK for short distance links with plenty of link budget. For longer links, the loss of 3-4dB is critical.

In contrast, the two-terminal method allows using different diplexers for the two channels, which gives a lot of freedom for channel selections and also makes it easier to obtain licenses from authorities.

Two-terminal method even allows using two different frequency band for each of the two channels for greater flexibility (requires different antennas for each channel).

The following table summarizes the proper use of two methods:

Two-Terminal Combination	**Sub-Channel Operation**
Longer distance links	Shorter distance links
When you have regulatory difficulties	When you have regulatory flexibility
When two channels do not fit in the diplexer range (use other sub-band or other frequency band)	When two channels can fit easily in the diplexer range (easier to do this with smaller channel bandwidth use)

6. Compression

Many vendors include compression as part of the calculation to achieve 1Gbps capacity. There are two types of compression – header compression and payload compression.

Of the two, header compression is more effective in that it will give you a more better result because the header can be more consistently compressed. However, the header is a relatively small part of the overall traffic, so the effect is not

Payment compression in contrast is seemingly where one will get a big gain via compression, but the effectiveness is far from consistent. Information theory tells you that compression works best when there is very little "information content", i.e. predictable and uniform information. By contrast, completely random information cannot be compressed. This means that the effectiveness of payload compression cannot be known and should be regarded as unreliable. A good rule of thumb may be 10% gain due to header and some payload compression.

The upshot is that compression will give you something, but you will never know how much. Solectek does have options for header and payload compression, but we would not factor in any compression enhancement in any of the link capacity numbers. We would rather reserve any compression gain as bonus for customers.

7. Summary

To sum up, a number of factors must be carefully considered for your 1Gbps PTP link:

- Important factors – modulation (largely link distance limited) and channel bandwidth (largely regulatory limited). Determine the best combination of these two factors to see what link capacities are possible.
- 1+0 links will NOT achieve 1Gbps for available channel bandwidth in most countries.
- 2+0 links will achieve 1Gbps without having to go to maximum modulation settings (limiting link distances).
- Sub-channel operation is the latest technique to achieve 2+0 for 1Gbps with a single radio link. Sub-channel operation does have some limits in terms of link distance and channel assignment difficulty (regulatory).
- Compression is largely a hit or miss and cannot be relied on for consistent performance. It is best to consider it a bonus when you can get extra capacity arising from compression.