# Layer-1, The RF Physical Layer is Critical to Performance of Wireless Networks and Capital Efficiency

**ISCO International**
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## Abstract

This paper illustrates the theory that an under performing, unmanaged RF physical layer will negatively impact the performance of the wireless network and the cost of operations. Having a solid, verifiable physical RF layer enables the upper layers to performance at peak efficiency making it essential to achieving consistent performance, maximum capacity and lower operating costs. These principles apply equally to CDMA, UMTS and LTE. We will offer a "toy model" to illustrate the concept. The specific conclusions from the paper will vary based on the specific network, measures of capacity and dollar assumptions. However the concept and the relationship between a poorly performing RF Physical Layer the resulting reduction in capital utilization and revenue remains the same regardless.


## Layer-1, The RF Physical Layer

No different than how it applies to wired Ethernet, voice and fiber networks, the ISO 7-Layer model applies to wireless networks. To date, the 7-layer model has been applied extensively to wired IP networks. When installing, trouble shooting or optimizing a wired IP network, a disciplined approach starting with the physical layer is the typical rule applied. Before touching the next layer, the performance of the preceding layer is verified. Starting at the physical layer, a clean link providing connectivity is verified before switching and routing are optimized, applications are tuned or QoS is re-configured.

Specifically, the parameters Carrier to Interference ratio (C to I), Adjacent Channel Selectivity (ACS) and Adjacent Channel Interference Ratio (ACIR) need to be assured to maximize spectrum utilization and performance. Active spectrum conditioning can help assure these aspects of the physical layer are at required levels.

## This same principle and discipline should apply to wireless networks

Smart phones and their data hungry applications have driven an explosion in demand for wireless capacity. The customer experience and expectation for consistent connectivity, high-speed transmission and delivery of data drives wireless network operators to provide optimal physical layer performance to ensure maximum spectral utility from their networks. Anything less leads to customer dissatisfaction, churn and loss of market share. Shown in Figure 1 is a summary of the well-defined 7-layer model for wireless networks. Layer-1, the physical RF layer, can be one of many air interfaces so this applied equally to UMTS and CDMA networks. Real-time knowledge of the condition of layer-1 and the ability to verify its integrity is the foundation for optimal performance of layers 2 through 7 in the ISO model and the wireless network.

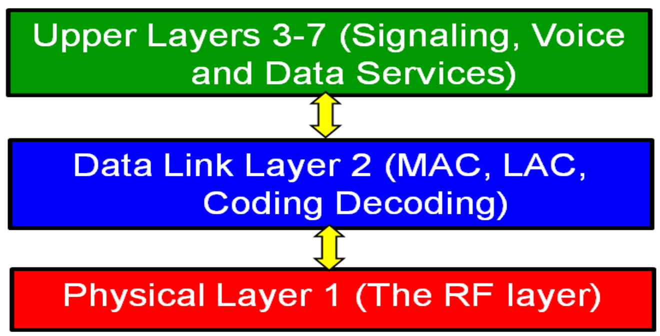


**Figure 1. ISO 7-Layer Model**

## Performance

Achieving maximum performance means delivering higher data rates, more throughput, fewer dropped calls, and reduced ineffective attempts, among other measures. A poor physical RF layer, layer-1, directly impacts all of these key performance indicators (KPI's). When the physical layer is not operating as engineered, the higher layer protocols will attempt to compensate for the poor condition, and performance will be negatively impacted. Excessive retransmissions, unnecessary incremental control traffic, and session layer terminations occur as a result of a less than optimal impaired RF physical layer. Not only does this impact performance and user experience, it will gobble up capacity and processing power on the Base Station and Fixed Network Switching Elements along with causing a reduction in RF coverage footprint.

## Maximum Capacity

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With RF as the physical layer the air interface is susceptible to performance affecting impacts from a variety of sources. Occurrences that impact RF performance are considered Physical Layer Impairments ("PLI's"). PLI's can have many originations. These can include loose or corroding connectors, aging antennas, rogue interferers from infinite sources, and ingress from high-power adjacent or border transmissions.

Unlike wired connections that enjoy shielded copper as the transmission medium in the physical layer, over the air links in wireless networks are more susceptible to PLI's and require clean conditioned spectrum to insure optimal performance especially on the challenged reverse link. Real-time active monitoring of the RF physical layer affords early notification of a problem in the very foundation of the link. Monitoring the physical layer in addition to conditioning the physical layer provides improved reliability, better in-building penetration and more effective data throughput with fewer NAKs and requests for retransmissions.

## Lower Operating Costs

When problems arise or performance is not as expected in a communication network, diagnostics and analysis should start at layer-1 and move up the stack. The ISO model and the associated discipline prescribes a methodology for trouble shooting that allows a systematic approach to diagnose and isolate problems. Step 1 is to have visibility into the physical layer to allow real-time assessment of the quality of layer-1 and the presence of PLI's. Having this knowledge helps technicians quickly determine whether or not the physical layer is a part of the problem or impacting performance. Without this visibility a technician can only guess whether or not the RF link is good, jeopardizing a timely resolution of problems and performance issues.

Step 2 is to protect and condition the physical layer to minimize the likelihood of PLI's corrupting the physical RF link. Corrosion and aging equipment are maintenance related, border and adjacent RF energy can possibly be addressed with planning, but interference is random and will occur. The sources of interference are infinite and ever-changing. They range from baby monitors to BDA's used on board ships, in automobiles, commercial and residential buildings and in DAS networks, to cable TV amplifiers, 2-way radios, and a variety of other wireless products. A microwave oven in a building can be amplified through a BDA and affect the performance of an entire cell site. If lucky, the technician can find this within a day. If not, given its random nature, the technician can spend weeks to find the source. Having a conditioned link with visibility into the physical RF layer will protect the wireless network against rogue interferers and aid the trouble shooting and resolution process.

## Capital Efficiency

Below Figure 2 graphically links together a relationship that is already known – the presence of unwanted interference reduces coverage area and the capacity of the radio link, therefore impacting the expected ROI on deployed capital. Whether UMTS or CDMA, as the power of PLI increases the capacity and coverage continue to decrease in a related manner. The calculated dollar impact on CDMA and UMTS will differ since one offers the availability of more carriers than the other but in either case there will be a impact on capital efficiency.

Initially, when the cell site was built it was assumed to cover a defined geographic area handling a projected traffic volume returning a forecasted financial contribution. Introducing PLI's immediately reduces the attainable revenue directly impacting the originating ROI that justified the investment. Said another way, if the cell site is operating at 100% of engineered capacity the service provider will be realizing 100% utilization of their network assets. Any degradation of performance means the assets are not producing the expected value or return on investment. The utilization of capital assets is reduced.

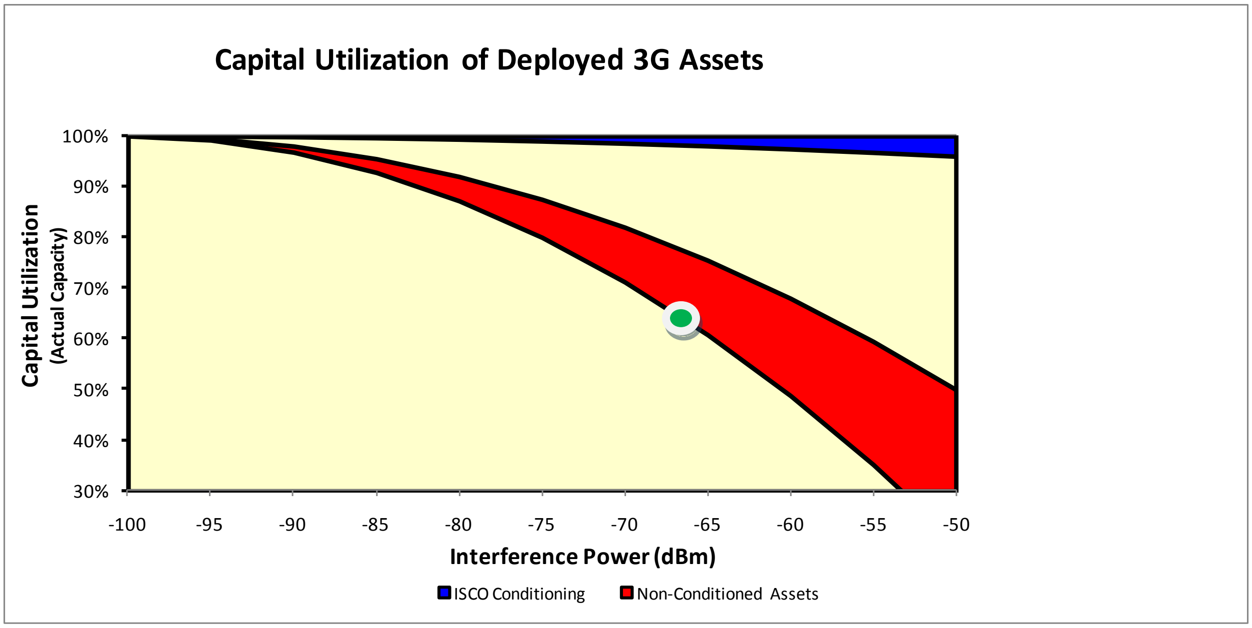


**Figure 2. The impact of PLI's on Capital Efficiency**

The graph in Figure 2 depicts the impact of PLI's on the return on capital investment for a UMTS network (a similar chart exists for CDMA networks.) This specific example was a real world situation where the cell site was experiencing a -65dBm interferer. The measured impact on performance was a 37% reduction in capacity. This operating point is plotted in GREEN on the chart in Figure 2 in the RED area of the graph. In all cases, cell sites are built, remote radio heads are deployed or more backhaul is installed with the expectation that the invested capital will operate at or very near its designed potential. When a PLI occurs, it will immediately impact the performance of deployed capital equipment, reduce the financial return, and extend the payback period.

Figure 3 below is a simple, sample calculation, "Toy Model" showing a dollar value that results from the impact of a degraded RF physical layer. The exact numbers will vary depending on the specific market situation but the concept and math remain the same. In this particular case, this was a real situation where the measured Erlangs for a single sector during busy hour before spectrum conditioning was measured to be 52. After installing active spectrum conditioning the PLI's were addressed and 82 busy hour Erlangs were measured. Applying 2.5₵as average revenue shows a loss of $270 for a single 6-hour busy-hour period or a 37% reduction. This value is plotted on the graph above in Figure 2.

| | | | Lost | |
|---|---|---|---|---|
| Erlangs | 82 | 52 | 30 | |
| Busy Hours | 6 | 6 | | |
| Busy Hour Minutes | 360 | 360 | | |
| BH MOU | 29,520 | 18,720 | 10,800 | 37% |
| Revenue per MOU | $ 0.025 | $ 0.025 | | |
| BH Revenue | $ 738 | $ 468 | $ 270 | 37% |

**Figure 3. Sample Calculation of Capital Efficiency**

*Notes:*

1. *This model assumes Erlangs for the measure of capacity and only considers a single sector. A similar model can be created for data throughput but conceptually the concept of lost capacity due to PLI's applies regardless of the unit being used to measure actual capacity.*
2. *This model is based on 2 UMTS carriers with 1 of the carriers being impaired. Conditioning both carriers and mitigating the impact of the interferer recovered 30 lost Erlangs of capacity returning the entire site to 82 Erlang engineered capacity.*
3. *Assuming the capacity of 2 UMTS carriers essentially equals 8 CDMA carriers delivering an average of 80 to 90 Erlangs, this same model can be applied once the real Erlang loss from a PLI is known.*

The exact parameters and variables in a service provider's specific ROI will vary from situation to situation and differ between UMTS and CDMA. The curves depicted in Figure 2 will then vary based on the exact model. But what will remain consistent will be the relationship between degraded performance and capital efficiency. Whether it is the reduction in voice traffic measured in reduced ERLANGS, or reduced Mbps throughput, or fewer offered calls, or lost revenue as result of churn, the underutilization of capital equipment and licensed spectrum or the incremental cost of overbuilding, the expected return on investment, ROI, will be reduced and more difficult to realize.

## Conclusion - A Solid, Verifiable RF Layer is Critical

Global mobile data traffic has increased by 160% in the past year growing more than 10 times faster than voice to 90 petabytes per month, or the equivalent of 23 million DVDs. This requires wireless operators to squeeze as much capacity from the existing spectrum they own as possible – maximum utilization is a must. Achieving maximum utilization starts with layer-1, a solid RF physical layer that the upper layers of the wireless network can rely upon. In addition to maximum utilization, having a solid layer-1 that is verifiable aids network optimization and trouble isolation which translates into lower operating costs and a higher performing wireless network.

For more information about how to maximize and protect the performance of the RF physical layer contact your ISCO International representative.

**About ISCO International**

ISCO International (www.iscointl.com) is a leading provider of reliable high-quality wireless telecommunications solutions supplying radio frequency management and "spectrum conditioning" products for wireless carriers worldwide. ISCO brings to the wireless market a suite of highly differentiated technologies and solutions for mobile operators, network infrastructure providers and other resellers of wireless products and software solutions. ISCO solutions include RF Digital Signal Processing, adaptive interference mitigation, software tunable band-pass and band-reject filters, and spectral analysis software tools to improve the performance and manageability of wireless networks. Conditioning the RF physical layer is a foundation of ISCO spectrum conditioning solutions.

More information about all ISCO wireless solutions can be obtained from the ISCO website at www.iscointl.com.

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