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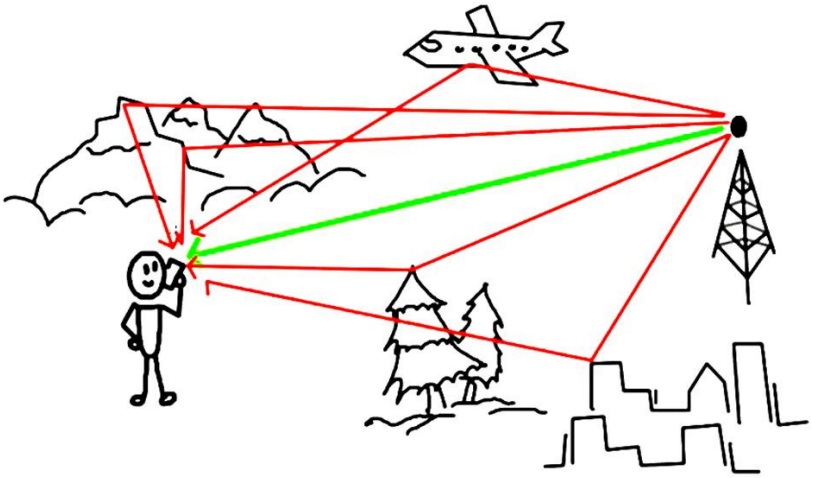
An introduction to Diversity.



The nice thing about radio communication is its ability to get you data anytime, anywhere, without being connected to a wire. This helps a lot when you're walking in a crowd so no one gets strangled. The miracle of radio waves - that they propagate everywhere - is also their biggest drawback. If you can't control the path over which the signal travels, you are going to get more than one copy of it at the receiver. Like ripples on a pond, reflections of the original wave bounce off of all sorts of objects and meet up at the antenna, either reinforcing or canceling each other. When a cell tower transmits a signal, it travels directly from the tower to the cell phone, but it also reflects off of buildings, trees, cars, mountains and other objects, and when those reflected signals reach the cell phone they can cancel each other and the direct signal. This is called a fade and it describes the situation where all the copies of the signal meet up at some point in time and space, and exactly cancel causing the connection to drop. It is a natural consequence of wave propagation in complex environments.

Fades have always existed, but weren't much of a problem in early generation cell systems because 1G, 2G and even 3G systems were primarily transmitting voice, not data. Because there isn't much information in the spoken word, the data rate is relatively low so it was easy to buffer the signal to work around fades. And because they don't last very long or occupy a very large area (1" – 3") they can be overcome by retransmitting the data once the fade ends. That doesn't work so well for 4G though, because data rates are so much higher, short fades wipe out a lot more information causing rebroadcasting to occur more often, which significantly lowers system throughput.

To work around fades, high data rate systems like 4G and Wi-Fi add a second path for the signal to get to the receiver and isolate this path as far away from the primary antenna as possible. Because wave cancellation occurs over a relatively small distance, say 1" to 3", installing two antennas on opposite ends of the device minimizes the chance of both being in a fade at the same time. This approach is called "diversity" and the second antenna is called the diversity antenna. Unlike in the main path, the diversity path only receives signals from the antenna and sends them to the receiver; it doesn't transmit signals out to the antenna. Not having to handle both incoming and outgoing signals reduces the number and performance required of the components used in the diversity channel compared to those in the main path, which has to handle both transmit and receive signals.

Because every 4G band carries data, every band has to have a second path to the receiver which means if the phone supports three LTE bands, it must have three routes in the main path and three in the diversity path. This wasn't a big deal for early 4G phones because most countries hadn't deployed networks and most OEMs only offered regional specific phones so the number of LTE bands in any one handset was small. But by 2015 things had changed; 4G networks were widely deployed and most of the large handset OEMs were moving to global phones. This led to a big increase in the number of LTE bands per phone, and big growth in RF content, much faster than we saw with 3G. Perhaps the best example of this is the iPhone which went from 7 LTE bands in iPhone 5 to 23 in iPhone 6S. Those 16 additional bands required more than 16 additional components in the main path and 16 in the diversity path. Little wonder then that RF content went from about $10 in iPhone 5 to about $24 in iPhone 6S. And with 50 bands allocated to LTE alone, band count per phone is only going to increase from here. As more operators push for more data, more bands will be activated and the size and cost of main and diversity channels will rise in step.

We've created a short video illustrating the reasons we need diversity and its impact on mobile phones. Our primary focus in this presentation is to reduce a complex concept to a digestible narrative rather than provide a comprehensive description of the details of diversity or the operation of RF circuits in handsets. Ideally, this tutorial will allow investors to understand how and why diversity is essential in 4G phones.

https://www.youtube.com/watch?v=ExX85XEVa7k

http://charterequityresearch.com/Videos/tabid/119/Default.aspx

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