Isolated Mode Antenna Technology for 4G

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Introduction

4G promises fast data rates, but delivering exceptional end-user experiences depends on the device antennas. As the only structure in a mobile device that communicates with the network, the antenna has always been important. Now it's especially critical given the industry's performance expectations and very challenging antenna requirements for 4G.

The challenges of 4G are multifaceted. First, 4G requires multiple-input, multiple-output (MIMO) technology, and mobile devices supporting MIMO typically have multiple antennas. To obtain the benefits of MIMO communications systems, antennas typically must be properly configured to take advantage of the independent signal paths that can exist in the communications channel environment. [1] With proper design, one antenna's radiation is prevented from traveling into the neighboring antenna and being absorbed by the opposite load circuitry. Typically, a combination of antenna separation and polarization is used to achieve the required signal isolation and independence. However, when the area inside devices such as smartphones, USB modems, and tablets is extremely limited, this approach often is not effective in meeting industrial design and performance criteria. Second, new LTE networks are expected to operate alongside all the existing services, such as 3G voice/data, Wi-Fi, Bluetooth, etc. Third, this problem gets even harder in the 700 MHz LTE band because the typical handset is not large enough to properly resonate at that frequency.

SkyCross addresses these challenges with its Isolated Mode Antenna Technology (iMAT®). iMAT antennas utilize a patented antenna design technique enabling a single, optimized MIMO antenna element to take the place of multiple antennas in small wireless devices. The benefits are faster data rates, greater coverage, increased reliability, lower cost, simpler integration, and improved aesthetic design for small wireless devices.

How iMAT Works

So how did SkyCross achieve the seemingly impossible task of designing a single antenna with multiple feeds? SkyCross realized that different modal excitations of a single radiating structure are possible while maintaining isolation between multiple feeds located on the same structure. Therefore, isolation between the feeds is possible. Also, the antenna pattern produced by each feed can be sufficiently different so signals transmitted or received between the different feed points are essentially independent—a requirement for higher gain diversity systems and high-throughput MIMO communications.

MIMO Metrics and Correlation Coefficient

For a MIMO communications system to fully exploit independence of signal channels, the transmitter and receiver must utilize multiple antennas with prescribed metrics. Metrics for MIMO communications systems have been developed, and many sources exist in the scientific literature. One metric commonly used to measure the potential for an antenna system to produce independent received signals is the antenna pattern correlation coefficient, which is defined by the following equation [2]:

$$\rho_p = \frac{\int_0^{2\pi}\int_0^{\pi/2} A_{12}\sin\theta d\theta d\varphi}{\sqrt{\int_0^{2\pi}\int_0^{\pi/2} A_{11}\sin\theta d\theta d\varphi}\sqrt{\int_0^{2\pi}\int_0^{\pi/2} A_{22}\sin\theta d\theta d\varphi}}$$

$$where \quad A_{mn}(\theta,\phi) = XE_{\theta m}(\theta,\phi)E^*_{\theta n}(\theta,\phi) + E_{\phi m}(\theta,\phi)E^*_{\phi n}(\theta,\phi)$$

$$and\ the\ cross-polarization\ power\ ratio \quad X = S_\theta / S_\varphi$$

This equation is specific to a two-antenna system and produces a coefficient whose magnitude is normalized to unity based on electric field components measured in a 3-D antenna range. If the antennas produce completely orthogonal patterns, the coefficient magnitude is zero. Conversely, two antennas with the same field component pattern produce a coefficient magnitude equal to one, as shown in Figure 1a. Because MIMO communications systems rely on separate spatio-temporal channels to achieve greater information transfer capacity, it is desirable to establish separate spatial directional response for each antenna to obtain the necessary channel independence. This creates a preference for sufficient pattern independence to produce a correlation coefficient magnitude below a certain threshold. The communications channel itself is also involved in achieving separate or independent spatio-temporal paths, and modifications to Equation 1 for those effects can be included for completeness. [3, 4]

Antenna Coupling or Isolation

The importance of isolation or reduced coupling between multiple feed antennas can't be over emphasized, since energy transmitted from one antenna can be absorbed by neighboring antenna(s). The situation is as shown in Figure 1b.

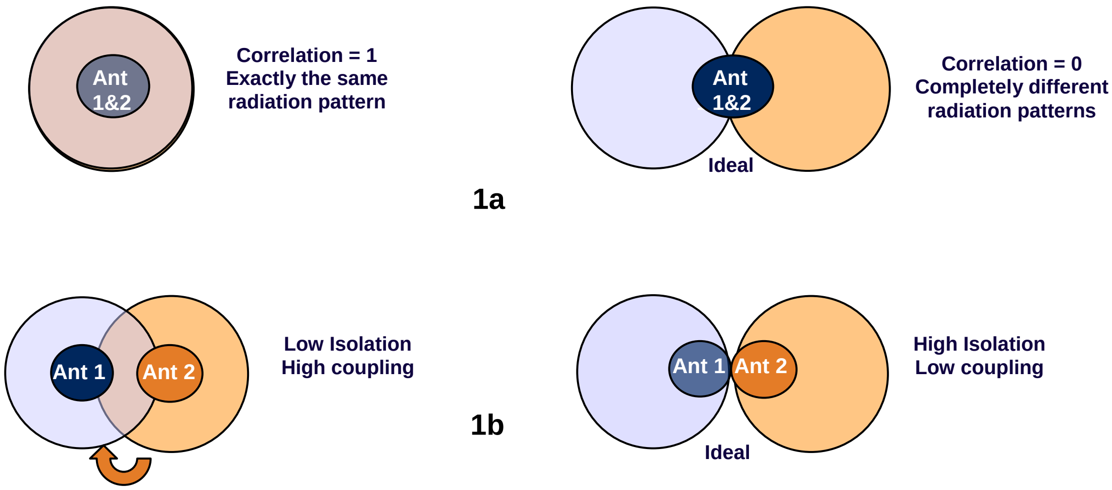

Figure 1. Antennas on the left have coupled near-radiation fields and highly correlated inputs, coupling energy from one into the other. The ideal situation is shown for the antennas at right where little radiation is coupled between antennas, and the correlation coefficient is zero.

Since iMAT provides sufficiently large isolation between feedpoints, the effect of unwanted coupling between antennas becomes negligible. his advantage can improve the radiation efficiency and therefore Total Radiated Power (TRP) by several dB (a factor of 1.5 or more) compared to similar non-iMAT solutions.

Coupling and its effect on antenna efficiency, and ultimately on TRP, is illustrated pictorially in Figure 2.

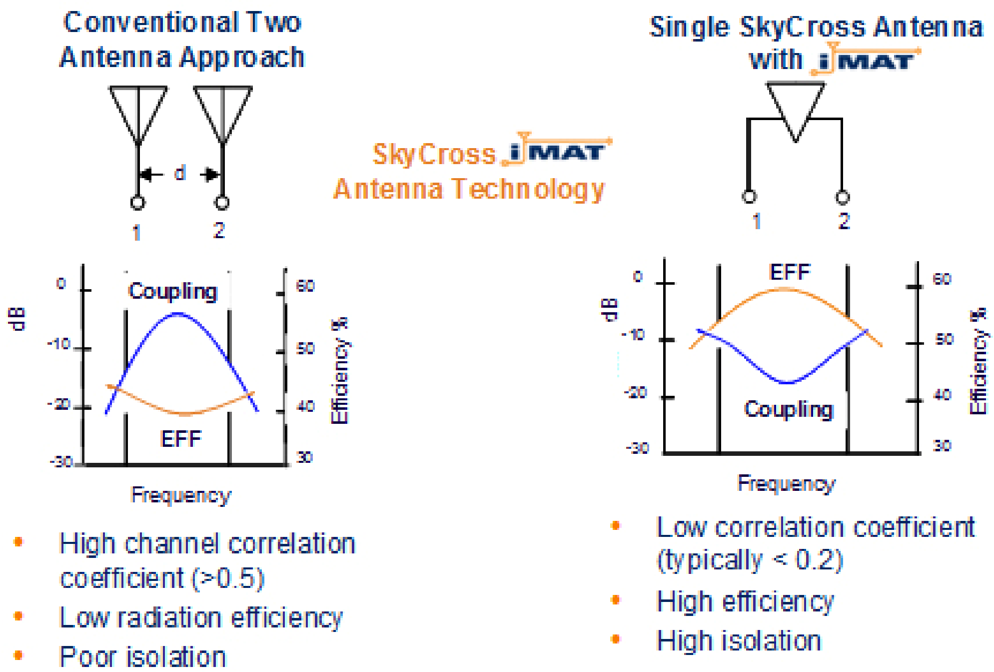

Figure 2. Illustration of the advantages of the iMAT single antenna over multiple individual antennas showing enhanced efficiency and reduced inter-element coupling

Currently, iMAT supports legacy networks and is essential for next generation protocols that require diversity or MIMO such as HSPA+, WiMAX, 802.11x, and LTE. iMAT creates a new way to think about creating a diversity or MIMO system. Ultimately, by using the advantages derived from better performing MIMO systems, end users will be able to realize the full potential of their wireless services and demand faster connections at an increasing rate.

iMAT WiMAX Technology Example

To illustrate the above effects and the benefit of the iMAT approach, refer to Figure 3 showing an example of a USB antenna application for the 2.5-2.7 GHz band. Shown is a typical USB device consisting of a printed circuit board (PCB) assembly enclosed in a plastic housing, with a USB connector at one end. The space available for the antennas is assumed to be at the opposite end of the PCB. The width of the device is 20 mm and the length and height available for the antennas are 10 mm and 2.5 mm, respectively. The majority of the PCB, between the antennas and the USB connector, is a continuous RF ground.
Two different antenna solutions are shown for comparison. The first consists of two meander line monopoles in the same form factor as illustrated in Figure 3. The distance from the ground available for the radiator is 10 mm, or $\lambda/12$ in free-space; however, the monopoles are made an effective $\lambda/4$ length through the use of a meander line, slow-wave structure. The second case considers the iMAT solution that includes a similar meander line loading method for space efficiency, but one that maintains a half-wave equivalent electrical length as a single resonator. The iMAT solution in this case uses a half-wave mode of a specially-shaped element where the location of each feed port is carefully configured to provide the desired isolation.

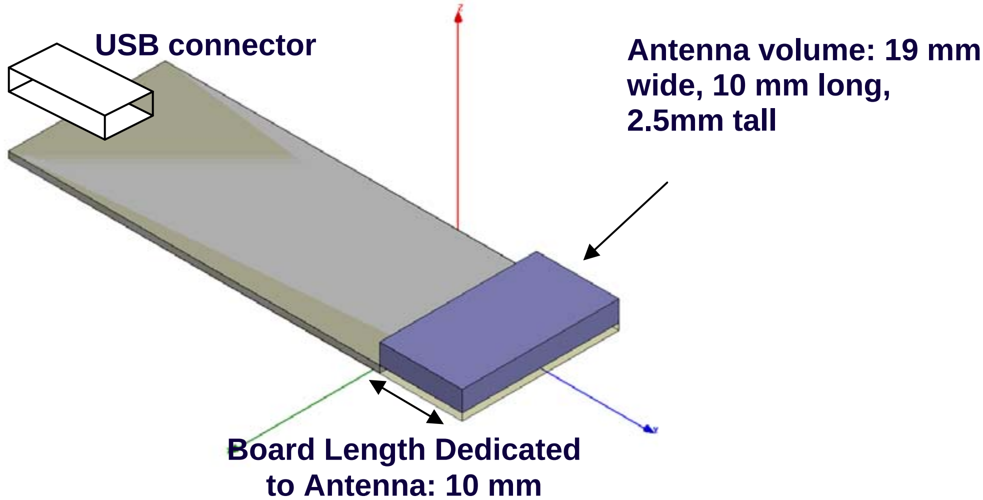

Figure 3. Example WiMAX USB antenna illustrating small antenna volume of 19mm wide by 10mm high and extending away from PCB distal end by 10mm, and measured correlation coefficient less than 0.2 and peak efficiency of 60 percent

A comparison of measured performance for the solutions is shown in Figure 4. Both approaches yield good impedance match with a VSWR of 2.5:1 or better over the band. (Figure 4a). However, the coupling, (S_{21}) for the monopoles is poor—about -4dB as shown in Figure 4b. The iMAT solution has considerably better isolation, with S_{21} values between -10 and -15 dB in the designated band.

The S_{21} value has a direct impact on efficiency due to signal loss to the neighboring antenna and its associated load. Not surprisingly, the iMAT solution shows better efficiency than the other solutions as shown in Figure 4c.

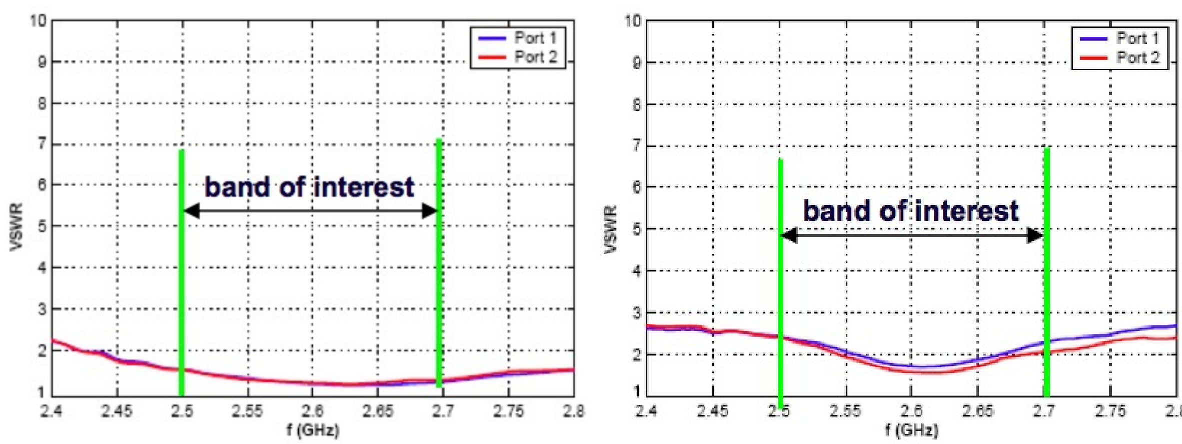

Figure 4a. VSWR Conventional Antennas vs iMAT Antenna

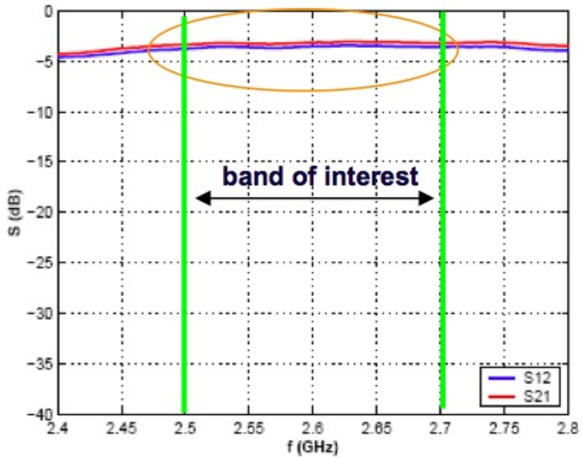

Figure 4b. S_{21} (Isolation) Conventional Antennas vs. iMAT Antenna

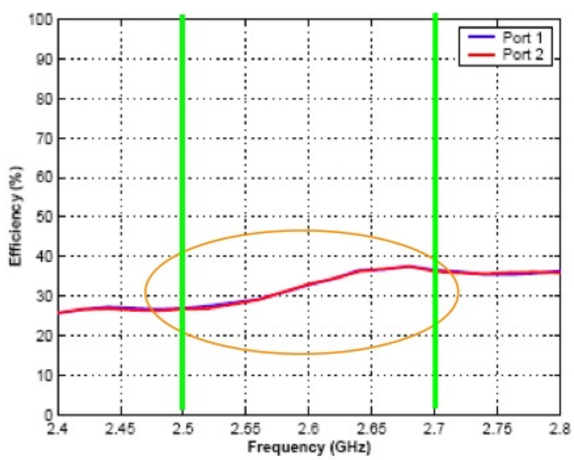

Figure 4c. Efficiency Conventional Antennas vs. iMAT Antenna

Figure 4. Comparison of (a) VSWR, (b) S_{21}, (c) Radiation Efficiency, and (d) Envelope Correlation Coefficient for 3 cases: two monopoles, two monopoles with ground plane isolation tab, and iMAT antenna showing advantages from the isolated mode methodology.

Although radiation efficiency is improved, an added benefit is the reduced correlation coefficient achievable with iMAT versus close proximity multiple antenna solutions. Correlation coefficients of less than 0.5-0.7 are desirable for MIMO and diversity communications systems. Although achieving these correlation coefficient values is possible with multiple antennas on a given platform, the iMAT solution is ready-made, requiring little additional engineering design. In addition, for those antenna systems not able to achieve low correlation values, the benefits of iMAT include improved system capacity and data rates.

Commercial Proof

The commercial benefits of iMAT are clearly demonstrated at the network level. In network Over-the-Air (OTA) testing, iMAT outperforms conventional antenna technology. The two

USB dongle configurations as illustrated above were testing in the field on a live WiMAX network. The tabulated data in Figure 5 shows the measured data rate in Mbps for both dongles. The measurements were performed back-to-back using the same receiver configuration. In all cases, the iMAT enabled dongle shows substantially higher data rates compared to the dongle using conventional antennas. The data rate improvement is up to 2.5X faster.

measured data

Location	Antenna	udp downlink goodput (Mbps)	CINR (dB)
Fringe Area 1	iMAT	1.900	12
	Non-iMAT	0.758	10
Fringe Area 2	iMAT	1.710	11
	Non-iMAT	1.130	10
Fringe Area 3	iMAT	0.497	6
	Non-iMAT	n/a	2

Figure 5. Throughput and CINR Conventional Antennas vs. iMAT Antenna

Summary

In summary, these examples show that iMAT makes diversity or MIMO systems possible, even in instances where the industry long ago decided such implementation was impossible. SkyCross has discovered a way to reap all the benefits of optimized multiple antennas—multiple radiation patterns and improved link performance gain leading to faster data rates, increased network capacity, and better reliability—in one small antenna.

End users want trendy devices with lots of features that perform well, and they want their devices to hold a charge for weeks. iMAT optimizes antennas to deliver a satisfying user experience. Higher gain and efficiency provide users with better signal strength, even when the nearest tower or base unit is far away. This capability reduces dropped calls, increases range, and enables faster data transfer for high-definition video, music, etc.

References:

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