Quantum Advances in GSM

Gain ICs

COMMUNICATE FASTER AND FURTHER

An exciting new breakthrough in wireless communication developed by Instantaneous Technologies, instantaneous wireless (IW), brings capabilities to global system for mobile communications (GSM) which far surpass those methods currently used. It has all the advantages of Gaussian minimum shift keying (GMSK) currently used in GSM but without the limitation of low bitrate. In specific, bitrate increases by 1661 times or transmission distances increase by 12 times, 144 times increase in area, keeping a constant bit error rate (BER) of $1x10^{-10}$ and all else equal, and at reduced cost, as in Figure 1. Cost and power usage of IW is significant lower as GMSK, currently used in GSM, is a merely a significantly more complex version of the frequency shift key (FSK) modulation used by IW.

These advances are owing to the elimination of down conversion, in Figure 2. Contemporary methods of radio frequency (RF) transmission involve down conversion to an immediate frequency (IF) or direct conversion which down converts to base frequencies directly (zero IF). IW eliminates both down conversions (direct and IF) reducing reception to essential operations only at the received frequency: amplify, filter and demodulate. This reduces receiver noise by orders of magnitude allowing IW to transmit further, with less bit energy, and at essentially zero bit error rate (BER), while achieving high bitrates and far surpassing quadrature modulation methods, including GMSK.

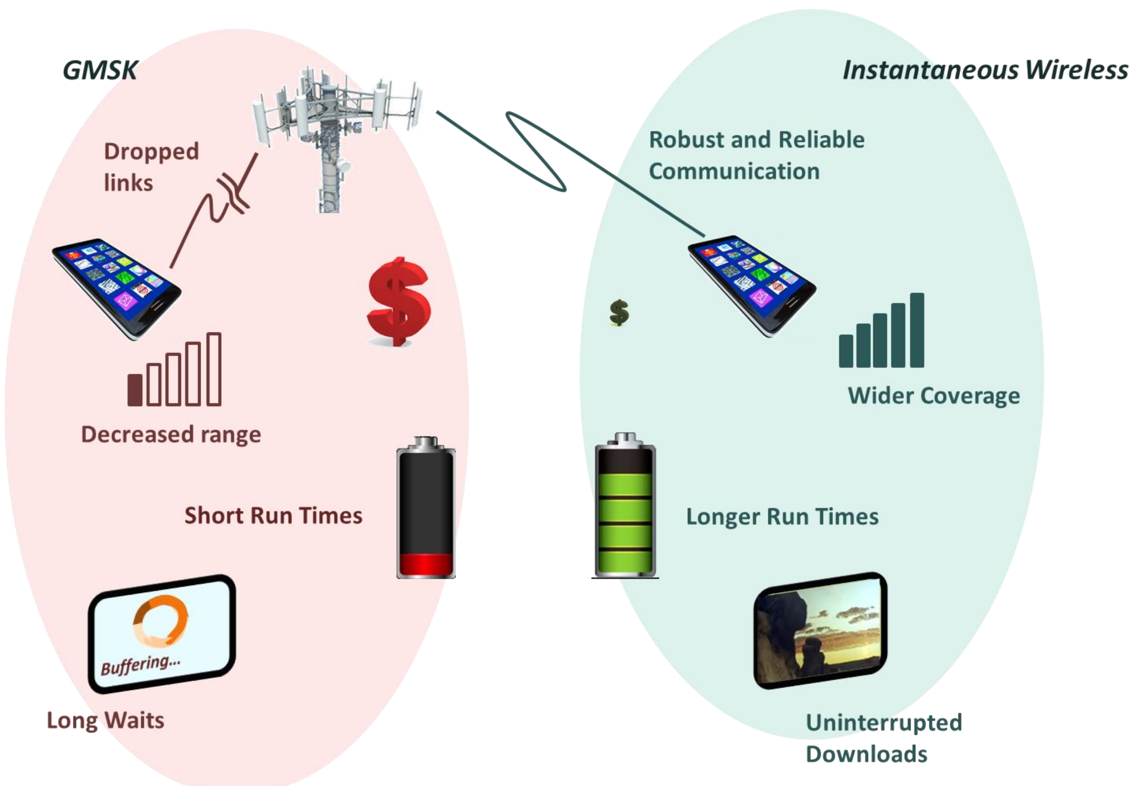


Figure 1. Orders of magnitude increase GSM performance.

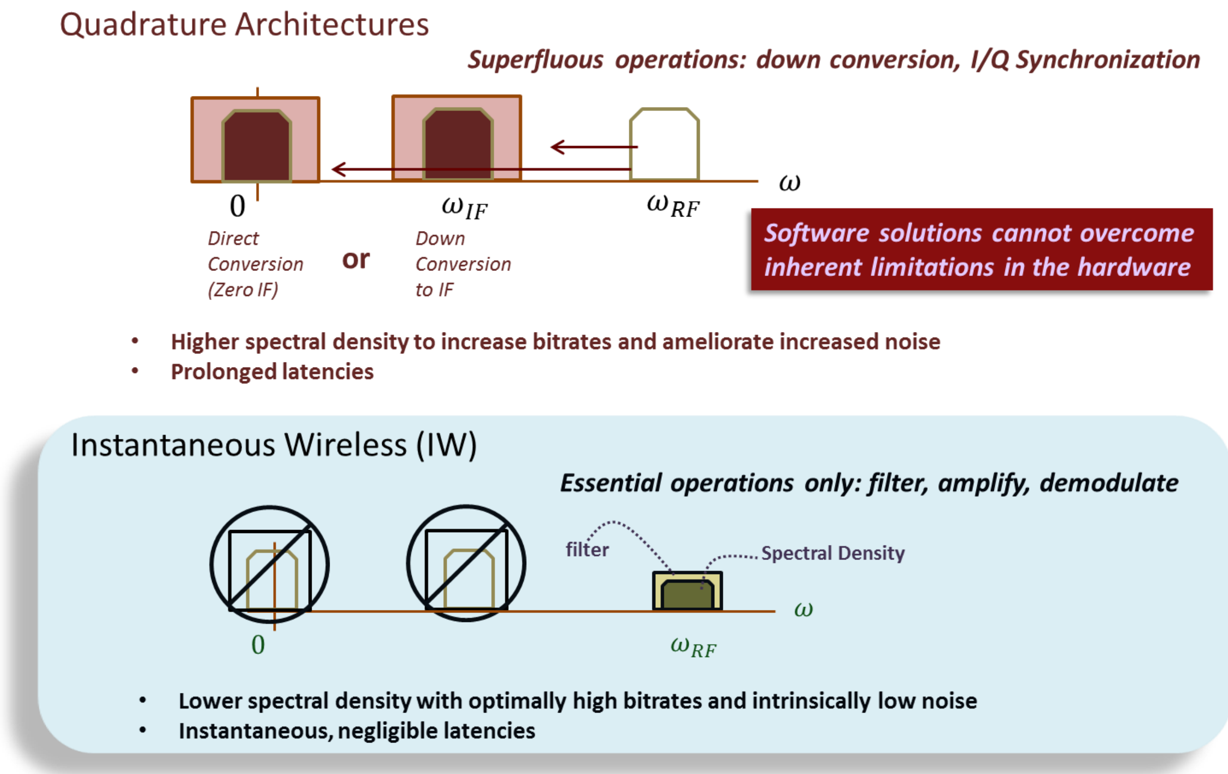


Figure 2. Simplify radio frequency (RF) reception to filter, amplify and demodulate only.

INSTANTANEOUS COMMUNICATION

Another salient IW advance is instantaneous communication. IW demodulation occurs within 10 ns, Figure 3, which is millions of times faster than quadrature methods. This eliminates interference from multipath reflections, as demodulation occurs much faster than the travel time of most reflected waves thus preventing overlap with the direct wave. This also translates into instantaneous (undetectable) frequency hopping for significantly increased security while keeping high bitrates.

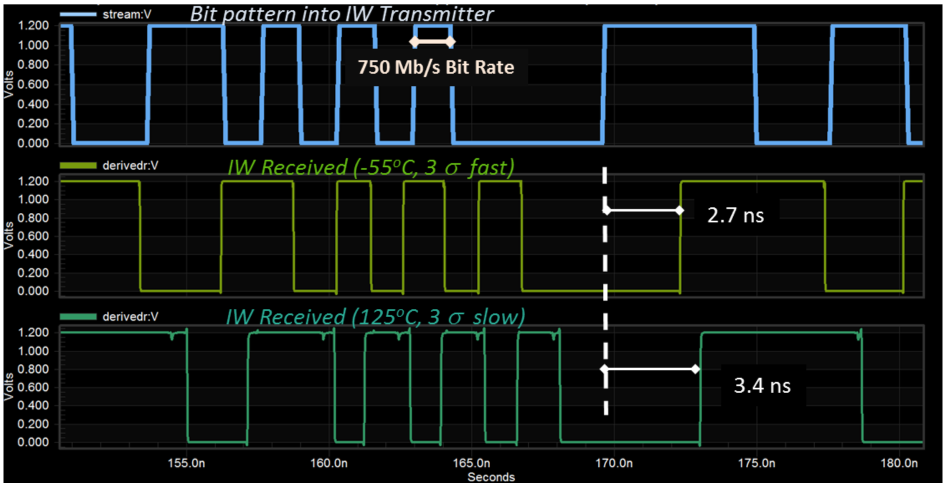


Figure 3. High bitrates with negligible latencies, transmitter to adjacent receiver with 60 dBm power at receiver.

INCREASED RELIABLILITYAND RANGE

IW inherently has extremely low noise, eliminating all of the down conversion and quadrature processing noise currently plaguing wireless communication. GMSK, currently used in GSM, adds a lot of complexity over the simpler FSK base specifically to bring the noise lower. IW FSK keeps the noise even lower than GMSK and avoids the increase in complexity GMSK adds to FSK, providing the best of both worlds. Figure 4 shows that at 100,000 times less average bit energy IW achieves the same BER as MSK, all else being equal. Unlike MSK, IW achieves the superior noise performance MSK does over other quadrature modulations, and even surpasses MSK, while achieving the higher bitrates other notoriously noisy quadrature modulations achieve, like quadrature amplitude modulation (QAM).

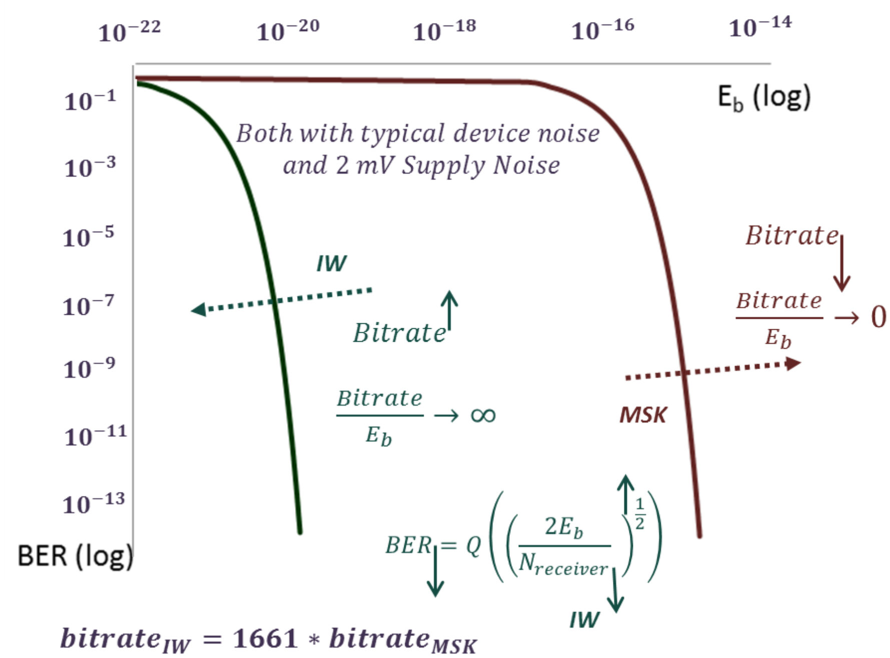


Figure 4. IW reduces BER with high bitrate, eliminating the bitrate to reliability tradeoff of quadrature modulations.

Given the even lower intrinsic noise of IW than MSK, Figure 5 shows that all else equal IW transmits significantly further, 12 times further or 144 times more area, at 1661 times higher bitrate and an equal reliability of 10^{-10} BER. The increase in received average bit energy per range, as well as the 100,000 times improvement in BER for IW is owing to the lower noise of IW, eliminating the down conversion and quadrature operations.

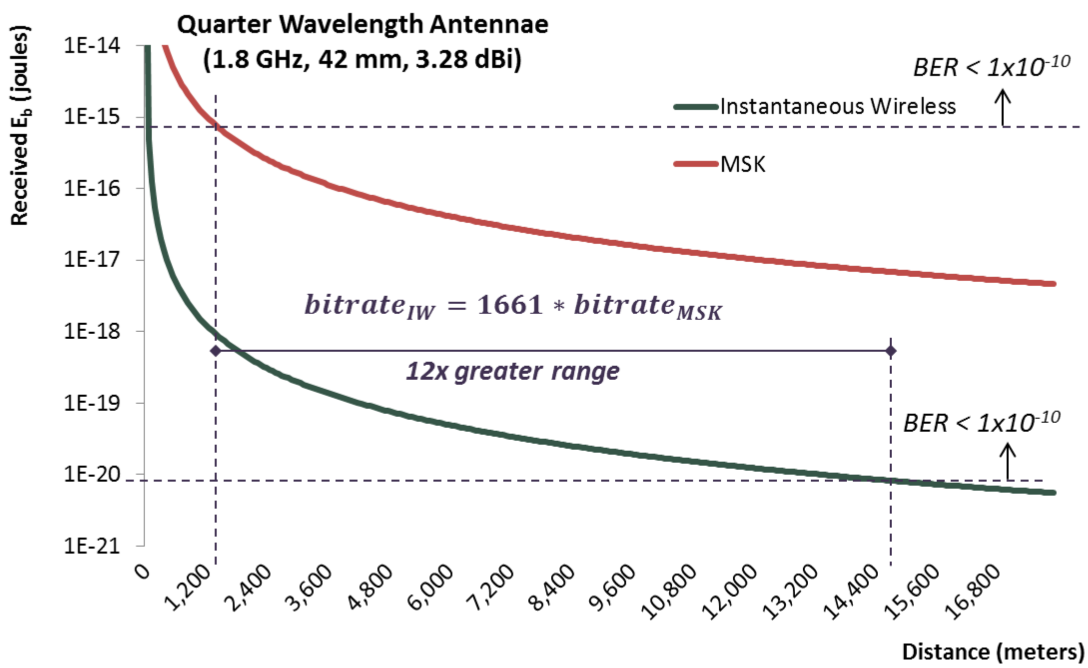


Figure 5. IW, at 1661x higher bitrate, transmits 12x further when both IW and MSK are set to the same reliability.

IW, as these data show, is essentially GMSK only with 1661 times faster bitrates and 12 times greater range. This increased range translates into 144 times increase in area, or coverage. A summary of benefits of IW relative to MSK (GMSK) is in Table 1.

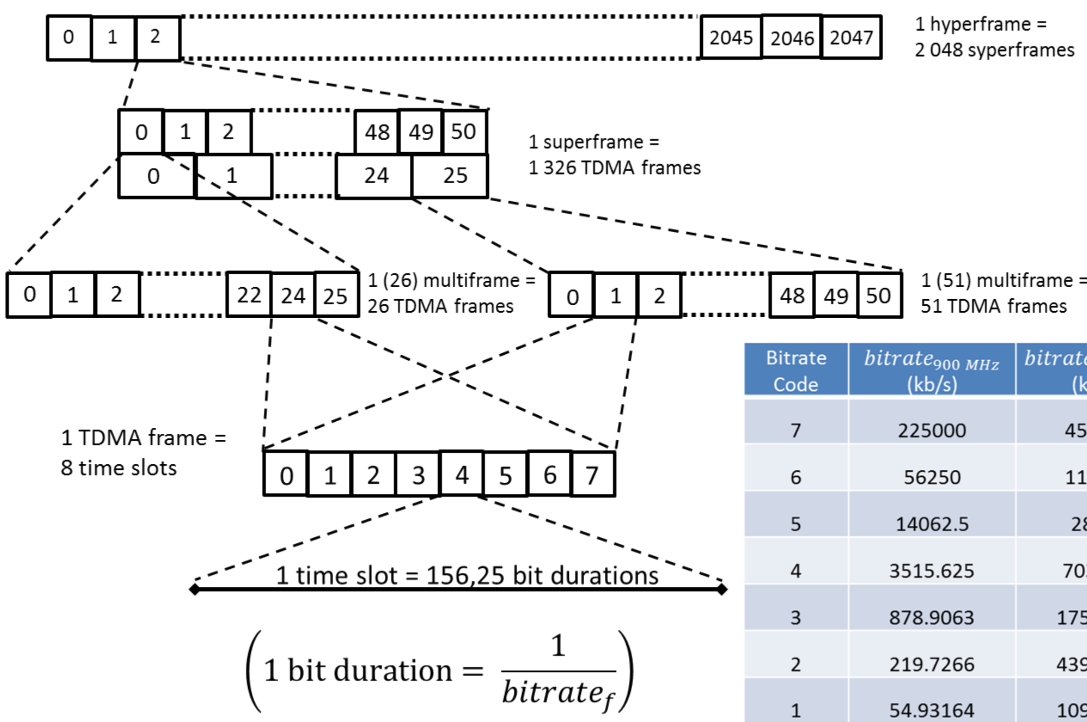
Table 1. Instantaneous Wireless advances over current MSK/GMSK.

Performance	Instantaneous Wireless (IW)	MSK	IW Improvement
Transmit Frequency (Hz)	1.8 G	1.8 G	
Bitrate (bps)	450,000,000	270,833	1661x
Range (m)	15,300	1320	12x
Bit Error Rate, BER	$10x10^{-10}$	$10x10^{-10}$	1x
Transmit Power (W)	0.3	0.3	1x
Received E_b (joules)	$1x10^{-20}$	$4x10^{-15}$	100,000x
Transition/Startup Time (s)	$8x10^{-9}$	1	125,000,000x

NEGLIGIBLE COST AND IMPACT TO EXISTING INFASTRUCTURE

Implementation costs of a GSM physical layer using IW are also substantially lower than those of quadrature methods. An IW transceiver can be placed next to a currently used transceiver on the same die, and take a small fraction of the area taken by existing transceiver. Or a stand-alone IW transceiver designed in a 55 nm process node can be mounted on existing printed circuit boards as a physical layer and interfaced to the existing protocol layers with little impact to the higher layers. The difference to the physical layer is the ability to now program in a range of bitrates, covering the current specified 270.833 kb/s, and extending up to 450 Mb/s, 1661 times faster, as shown in Figure 7. The only accommodation the higher network layers would have to make is to allow for higher bitrates, which should not be problematic as physical layers are typically the limiters to bandwidth.

The IW FSK is very similar to the GMSK modulation of GSM in immunity to noise, both modulating phase only. However IW FSK provides orders of magnitude faster bitrates than GMSK can provide.



Bitrate Code	$bitrate_{900\ MHz}$ (kb/s)	$bitrate_{1800\ MHz}$ (kb/s)
7	225000	450000
6	56250	112500
5	14062.5	28125
4	3515.625	7031.25
3	878.9063	1757.813
2	219.7266	439.4531
1	54.93164	109.8633
0	13.73291	27.46582

Figure 7. IW GSM physical layer, minimal impact to existing specification.

MODELING

IW

Both device noise and on-die supply noise were modeled for the cascade and range plots in

Figures 4 and 5. The same noise (1) was used for both IW and MSK to ensure equivalent comparison. Device parameters define the most dominant device noise at higher frequencies, thermal noise, summed with on-die supply noise for overall Gaussian or white noise.

$$\sigma_w = 1.373\sqrt{\frac{kT}{\sqrt{K'\frac{W}{L}I_D}}} + \sigma_{supply} \tag{1}$$

IW modulated signal is (2). By taking the derivative of (2) and the value at ¾ of the period, corresponding to the rising edge of the signal, the standard deviation amplitude noise is converted into standard deviation phase noise (3).

$$iw(t) = \begin{cases} \sqrt{2rE_b f_b}\cos(2\pi f_i t), & 0 \le t < \frac{1}{2f_b} \\ 0, & otherwise \end{cases} \tag{2}$$

$where:$

$f_i = f_c + (2i-3)f_d \quad for\ i = 1,2$

$f_b \sim modulation\ frequency, \frac{f_c}{4}$

$f_d \sim modulation\ amplitude$

$f_c \sim carrier\ frequency$

Using (3), the standard deviation of noise, and (4) the mean, the BER, using the Q function, for IW becomes (5).

$$\sigma_{\delta_t} = \frac{\sigma_w}{2\pi f_c\sqrt{2rE_b f_b}} \tag{3}$$

$$\mu = -\frac{1}{f_d} \tag{4}$$

$$BER_{iw} = Q\left(\frac{2\pi f_c\sqrt{rE_b f_c}}{f_d\left(\sqrt{\frac{kT}{\sqrt{K'\frac{W}{L}I_D}}} + \frac{\sigma_{supply}}{1.373}\right)}\right) \tag{5}$$

MSK

Similarly for MSK, the modulated signal is (6).

$$msk(t) = \begin{cases} \sqrt{2rE_b f_b}(\cos(\theta(t))\cos(2\pi f_c t) - \sin(\theta(t))\sin(2\pi f_c t)), & 0 \le t < \frac{1}{2f_b} \\ 0, & otherwise \end{cases} \tag{6}$$

$where:$

$f_b \sim modulation\ frequency$

$f_c \sim carrier\ frequency$

Converting amplitude noise to phase noise, same as was done with IW, yields standard deviation (7) and mean (8). The resulting BER, used to generate MSK cascade plots, is (9) where the actual value is doubled, as down conversion effectively doubles the noise under typical conditions.

$$\sigma_{\delta_t} = \frac{\sigma_w}{2\pi f_c \cos\left(\frac{3\pi f_d}{8f_c}\right)\sqrt{2rE_b f_b}} \tag{7}$$

$$\mu = -\frac{1}{2f_d} \tag{8}$$

$$BER_{msk} = Q\left(\frac{0.5\pi f_c \cos\left(\frac{3\pi f_d}{8f_c}\right)\sqrt{rE_b f_b}}{f_d\left(\sqrt{\frac{kT}{\sqrt{K'\frac{W}{L}I_D}}} + \frac{\sigma_{supply}}{1.373}\right)}\right) \tag{9}$$

The equations for effectively received average bit energy, for MSK and IW in Figure 5 are (10) and (11). Using Friis transmission equation, and signal space minus the respective noise for both, the higher noise of MSK relative to IW is readily observable. The same power transmitted for IW spreads to half the power for each of the two phase-synchronized MSK signals. Increased reliability and transmission range while still achieving desired bitrates are industry-changing breakthroughs that IW offers.

$$E_{b_{receive_{msk}}} = \left(\frac{1}{f_{b_{msk}}}\right)\left(\frac{2P_{transmit_{msk}}}{m} - 3(4)\left(1.373\left(\frac{kT}{\sqrt{K'\frac{W}{L}I_D}}\right)^{\frac{1}{2}} + \sigma_{supply}\right)\right)\left(\frac{\lambda}{4\pi Distance}\right)^2 {G_o}^2 \tag{10}$$

$$E_{b_{receive_{iw}}} = \left(\frac{1}{f_{b_{iw}}}\right)\left(\frac{2P_{transmit_{iw}}}{m} - 3\left(1.373\left(\frac{kT}{\sqrt{K'\frac{W}{L}I_D}}\right)^{\frac{1}{2}} + \sigma_{supply}\right)\right)\left(\frac{\lambda}{4\pi Distance}\right)^2 {G_o}^2 \tag{11}$$

QUANTUM ADVANCES IMPACT ALL WIRELESS

IW, a truly breakthrough technology in wireless communication, surpasses, often by orders of magnitude, quadrature architectures, now in common use, in all aspects of wireless communication. As such IW is well poised to supplant existing wireless technologies and offer quantum advances to all wireless applications, as well as create entirely new wireless applications owing to IW instantaneous communications, orders of magnitude faster and further than existing methods.

These quantum advances and novel capabilities substantially enhance GSM as a new ideal wireless physical layer with negligible impact to existing infrastructure and specifications, except for much faster bitrates and increased range and reliability. IW is essentially GMSK only with 1661 times faster bitrates and 12 times greater range. SCADA especially benefits from the increased range and reliability of IW.