RTT TECHNOLOGY TOPIC
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Interference Cancellation in the RF and Optical Domain

Interference within and between mobile handsets is traditionally managed by a combination of frequency domain and time domain filtering.

In the frequency domain much of the filtering, specifically the definition of the pass band and duplex gap is done by acoustic filters but for a number of years there has been strong academic interest in using interference cancellation to prevent TX desensitization of the RX path within the handset.

Coupling loss generally mitigates user to user interference but signal cancellation across the duplex gap could also have theoretical benefits.

In this month's technology topic we review a paper by Interdigital Europe Ltd documenting the progress being made with analogue and digital cancellation techniques and a paper from Photonic Systems proposing a circulator realized in an optical phase cancellation device.

Translating RF signals into the optical domain is a well-established principle used in RF over fibre in distributed antenna systems, allowing multiple RF signals to be combined into a low loss and low cost transport layer. Examples include RF over fibre in cable TV systems where the RF, typically between 54 and 870 MHz, is converted to modulated light using 1310 nm or 1550 nm laser optics.

An RF to optical transform may however also be useful in solving some of the filter challenges in next generation mobile broadband user devices and might provide an efficient mechanism for cancelling out unwanted signal energy both within a handset and between spectrally and geographically proximate users.

In the RF domain, analogue and digital interference cancellation is becoming more efficient and effective. An innovative combination of RF and optical phase cancellation might therefore yield useful performance improvements.

This includes the potential ability to support full duplex on a single channel avoiding the need for a frequency duplex or duplex gap and or time slot separation. This could substantially improve spectral utilization and significantly simplify the present spectral allocation and auction process.

Read on

The big challenge within mobile networks has always been to prevent high level transmit signals swamping low level receive signals which can be 100 dB lower in power.

In FDD networks this is achieved by separating user specific transmit and receive paths. This is known as the duplex spacing.

For example a 900 MHz mobile transmit channel is 45 MHz below the receive channel.

In TDD networks the separation is achieved in the time domain rather than the frequency domain with time slots reserved for transmit or receive.

It is possible to combine both techniques and have frequency and time domain separation. GSM is an example. This is usually described as half duplex. The advantage is that filtering in the handset is simpler, filter costs are lower and there will be less insertion loss. The maximum achievable data rate within a defined channel bandwidth will however be lower.

HSPA and LTE both use full duplex and transmit and receive simultaneously but the duplex spacing has disadvantages.

Because the uplink is at a different frequency to the downlink, the channel sounding has to be realized bi- directionally. This absorbs bandwidth and power and introduces additional latency.

Users also have to be protected from one another. This means the lower pass band has to be separated from the upper pass band by what is known as the duplex gap.

In a GSM 900 network the lower pass band of 35 MHz is separated from the upper 35 MHz pass band by a gap of 10 MHz

The acoustic duplex filters therefore have two functions. They keep transmit energy within the handset away from the duplexed spaced receive path but also define the lower and upper edges of the duplex gap so that a user in the highest channel in the mobile transmit path does not interfere with a geographically proximate user on the lowest channel of the mobile receive band.

In practice this arrangement works well but theoretically it would be more efficient (more statistical multiplexing gain and improved scheduler efficiency) if users could share a single channel rather than multiplexing across two channels. There would also be less signalling overhead and improved channel latency.

However this requires at least 100 dB of separation to be achieved within the user device.

Some separation could be achievable by sending transmit and receive signals through separate antennas though there is not enough space to do this in a modern mobile.

Other signal cancellation mechanisms therefore have to be used.

Unwanted signal energy can be cancelled out using some combination of frequency separation (FDD), time separation (TDD) or phase cancellation.

Phase cancellation only works if you have can acquire knowledge of the phase characteristics of the transmitted signal. This is achieved by having reference signals and training sequences of known amplitude and phase accurately referenced in time and frequency embedded in the information data.

The process is then dependent on managing to avoid or correct for amplitude to phase distortion.

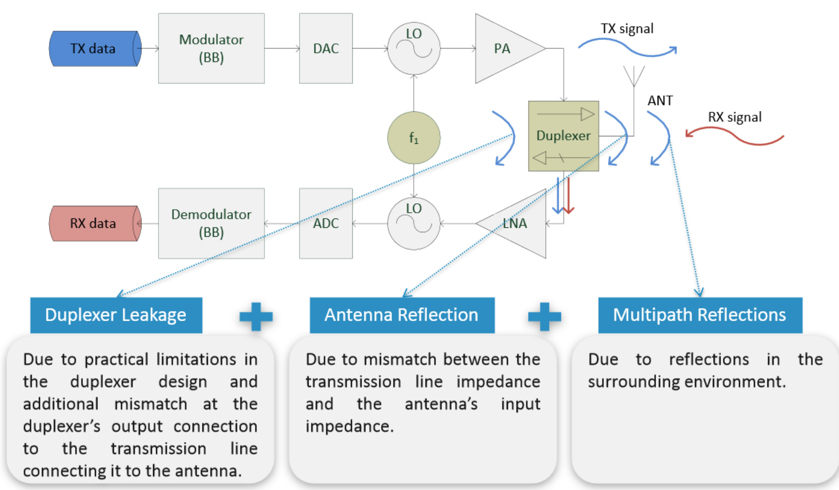
Phase cancellation can be applied in the analogue and digital domain and both are usually used together.

A paper presented by InterDigital Europe Ltd at a recent Cambridge Wireless event highlighted the progress presently made with these techniques over the past three years.

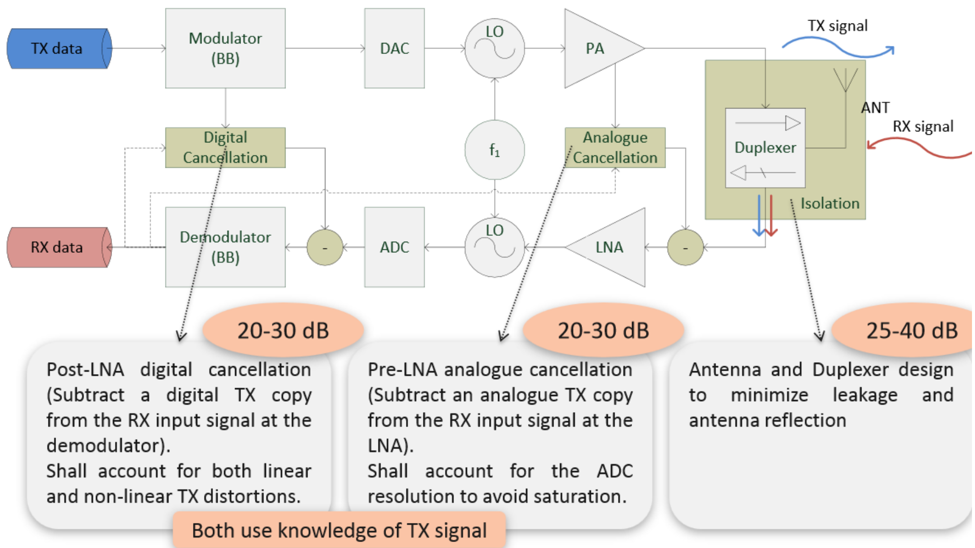
http://www.cambridgewireless.co.uk/crmapp/EventResource.aspx?objid=45190

The paper describes the sources of self-interference in a handset including reflected re-entrant energy coming back into the antenna, reflected energy caused by antenna mismatch and duplexer leakage, also a function of mismatch.

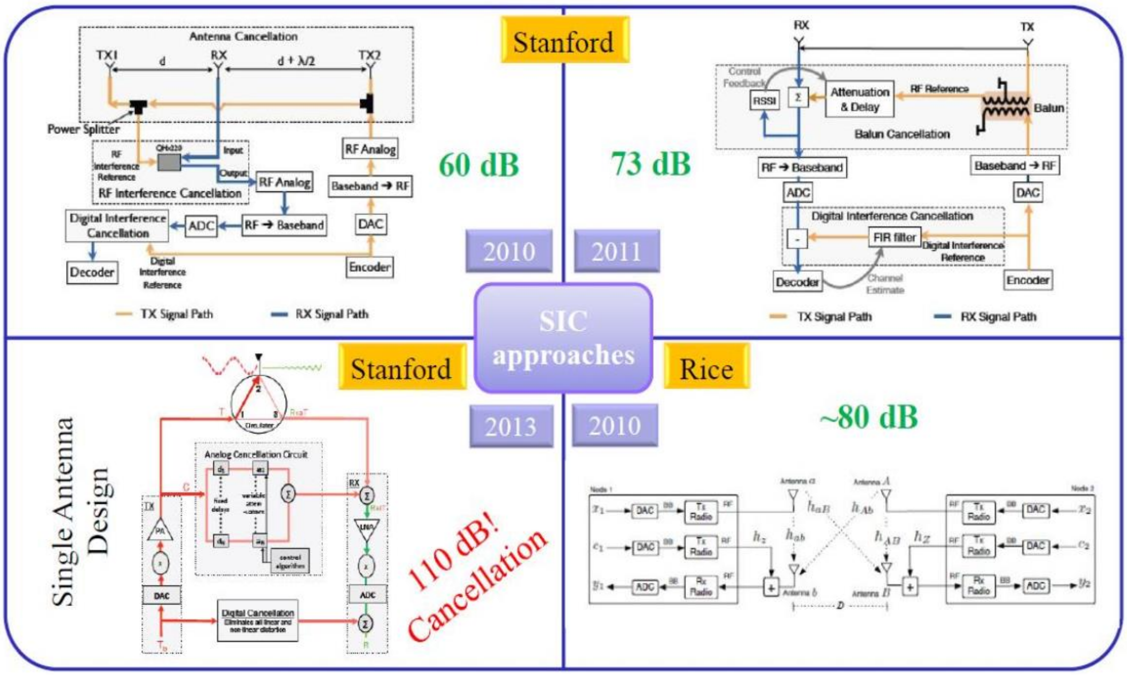
Self-Interference



Cancellation Approach (Cont'd)



The presentation showed the signal cancellation process with 25 to 40 dB delivered from the duplexer and 20 to 30 dB from analogue and digital cancellation.



Research at Stanford University was also referenced showing the improvement made over the past three years with a claimed 110 dB now being available coupled through a single antenna.

The system is however bandwidth limited but this could potentially be overcome by implementing an RF to optical transform, realising the phase cancellation functions of an RF isolator in the optical domain.

An RF isolator, also known as a circulator works by summing and differencing the RF phase of two waves travelling in opposite directions around the circumference of a ferrite disk. It is a two port device with constructive interference at one port and constructive interference at the second port.

The bandwidth of the device will however be significantly less than an octave (1 GHz to 2 GHz for example) and the amount of available isolation will be of the order of 20 dB

An alternative proposed by Photonic Systems (follow link for full article) is an optical modulator.

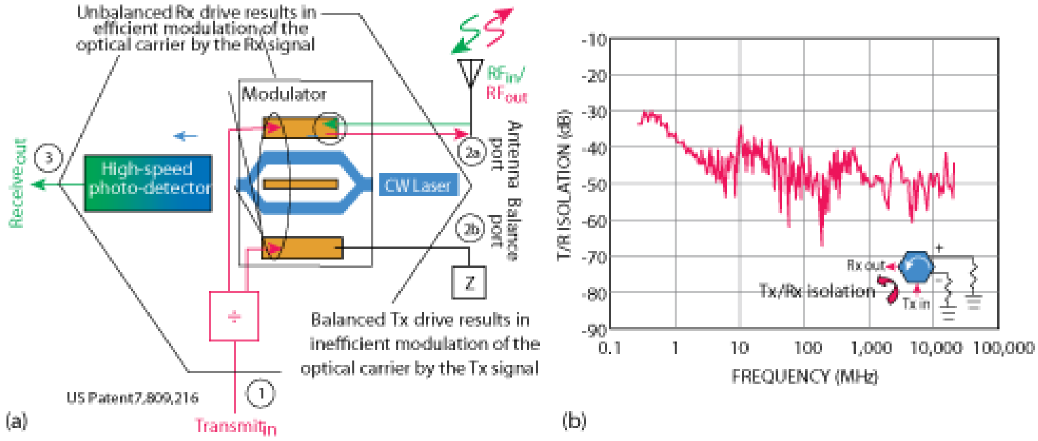
http://www.microwavejournal.com/articles/22950-maximizing-rf-spectrum-utilization-with-simultaneous-transmit-and-receive

The receive signal is routed through an unbalanced drive and efficiently modulated on to the optical carrier. The transmit signal is routed through a balanced drive and inefficiently modulated on to the carrier.

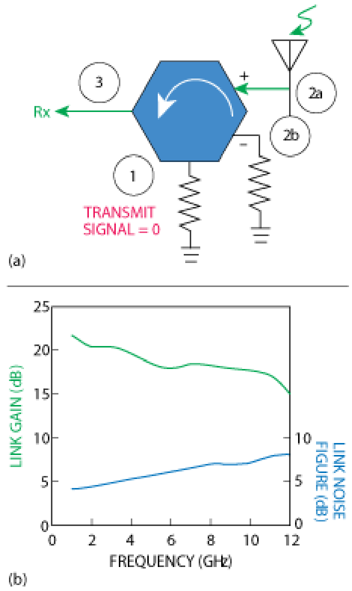
Achievable isolation is of the order of 40 dB over four decades of bandwidth into a 50 ohm load.

The photonic components include a CW laser an optical modulator and a photo detector. These devices would previously have had noise figures of the order of 20 dB and high insertion loss but photonic links are now available that have lower noise and positive link gain.

The suggested achievable noise figure operating between 700 MHz and 6 GHz is of the order of 4 to 6 dB with 17 to 21 dB of gain.



Mismatch is managed by connecting a variable impedance to an additional ‘antenna balance’ port which replicates antenna impedance versus frequency.



At frequencies where the impedance at the two bidirectional ports are equal, the transmit signal at Port 1 is routed to the antenna connected to port 2 and the signal received by the antenna is routed to Port 3. Port 3 is isolated from Port 1 because the portion of the transmit signal that is reflected by the antenna back into Port 2 (a) is balanced by the transmit signal reflected back into the ‘balance’ port 2(b) by the impedance connected to the fourth port.

This analogue cancellation process on its own is unlikely to provide sufficient TX/RX isolation due to limitations of the optical modulator and differences between the antenna impedances and the balance.

However provided there is sufficient suppression of the transmit signal in the analogue front end to preserve RX linearity then digital cancellation should be able to do the rest of the job. The transceiver knows what it is transmitting so should be able to produce an adequate estimate that can then be subtracted.

http://www.photonicsinc.com/star_fm_demo.html

The power budget implications of this are not described but will be significant. The real benefit of an optical transform is extremely wide bandwidth for the fundamental reason that even 100 GHz of RF bandwidth is a small fractional bandwidth when modulated on to a 200 THz optical carrier (as shown by the four decades of bandwidth in plot (b) above). As we don’t actually need this amount of RF bandwidth for at least the foreseeable future it is likely that electronic rather than optical solutions will remain generally better matched to mobile handset applications.

It is also unlikely that the global operator community would or could precipitately abandon traditional FDD and the prospect of having some but not all devices transmitting and receiving in a transmit or receive pass band might cause user to user interference issues which would be hard to address.

That aside, improvements in traditional analogue and digital interference cancellation techniques combined with an optical transform could deliver an interesting alternative to conventional RF front end design.

CW Tec Technology Conference in London March 24 2015
Interference cancellation and coexistence management will be discussed in the CW Technology Conference in London next March which Interdigital Europe Limited are kindly co-sponsoring.

Spaces on this event are limited so it's useful to book now rather than later

http://www.cambridgewireless.co.uk/cwtec/
http://www.cambridgewireless.co.uk/cwtec/programme/

Our thanks to Alain Mourad of Interdigital Europe Ltd and Charles Cox of Photonics Systems Inc for allowing us to reference their research papers and for reading a draft of this article (though any residual mistakes are our own).

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http://www.rttonline.com/tt/TT1998_008.pdf

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http://www.epsrc.ac.uk/funding/calls/newmaterialsrfmwworkshopeoi/

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