HUGHES
An EchoStar Company

Equalization and Predistortion for Mitigation of VSAT Channel Impairments

In recent years, the satellite communications industry has seen various improvements in VSAT system efficiency and coding schemes through a number of Digital Video Broadcasting Standard extensions. However, the benefits of these improvements and extensions are not yet completely clear where linear and nonlinear impairments impact end-to-end link performance. These impairments must be taken into careful consideration since they limit the achievable spectral efficiency for a given system architecture and link budget. Hughes has implemented an equalization scheme in the JUPITER™ System to tackle distortions caused by impairments in VSAT channels.

Impairments in VSAT Channels

Linear impairments

Linear impairments, such as group delay and amplitude distortion, are caused by filters in the gateway, satellite, and terminals, as well as the connecting cables in the gateway and terminals. Linear impairment causes distortion of a signal in which a symbol interferes with subsequent symbols. This is known as Intersymbol Interference (ISI). The presence of ISI introduces errors at the receiver device.

In the satellite channel, frequency response is dominated by the IMUX and OMUX filters on board the payload. Typically, these split the total input bandwidth in channels, also referred to as transponders, of various frequencies. Distortion, due to the group delay variations in the vicinity of the cut-off frequencies, leads to a lower symbol rate. Additionally, application of a roll-off factor to avoid filtering out of spectral content further lowers the achievable symbol rate. These considerations apply unless an efficient equalization scheme is implemented at either the transmitter or receiver end. Although basic equalization techniques are implemented in DVB-S2 chipsets, it is recommended that manufacturers include advanced equalization techniques in DVB-S2X implementations. This can help gain a spectral efficiency improvement of 7% to 9% compared to conventional receivers.

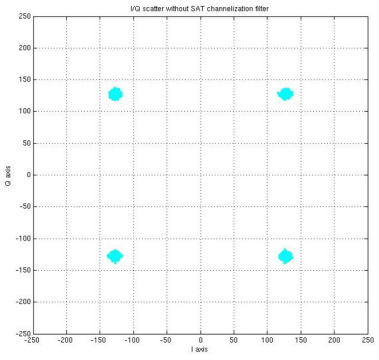
Nonlinear impairments

Nonlinear impairments are caused by High Performance Amplifiers (HPAs) in the gateway, satellite, and terminals. At the ground stations, distortion can be reduced in the uplink by operating at a large output back-off. This is feasible since power supply and HPA dimensions at the ground station are not critical. However, this is not the case on board the satellite, where power is a scarce resource.

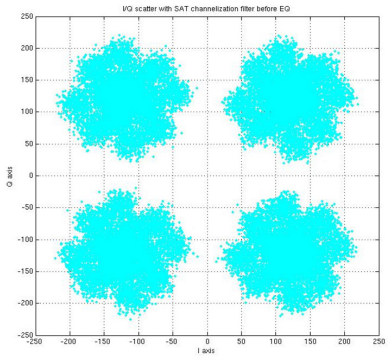
Two types of distortions are generally caused by nonlinear impairments: the Adjacent Channel Interference (ACI), which is interference caused by extraneous power from a signal in an adjacent channel, and the Constellation Warping, in which constellation points are not on a rectangular grid. Distortions due to nonlinear impairments can be mitigated using efficient predistortion schemes.

Mitigating impairments through an equalizer

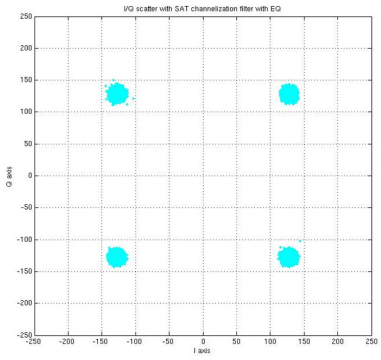
Hughes has implemented an equalizer at the JUPITER System remote terminals to effectively mitigate the distortions caused by impairments in VSAT channels. In Hughes' equalizer implementation, with ongoing traffic signal, linear impairments are mitigated using a finite impulse response filter structure. The back-off required depends on the peak-to-average ratio. Higher order modulations and multicarriers would require a higher peak-to-average ratio, resulting in higher back-off. The figures below show scatter diagrams of QPSK signaling with and without distortion and an equalizer.



QPSK signaling without linear impairments



QPSK signaling with linear impairments, no equalizer



QPSK signaling with linear impairments and an equalizer

Further, the Hughes equalizer is fractionally spaced, meaning that equalization is spaced in half-symbol intervals. Fractional spaced equalizers are insensitive to symbol timing offset. The equalizer is updated in a data-aided manner using known pilot symbols and least means squares algorithm. Additionally, the equalizer also compensates for the effects of echoes in the antenna cable distortion.

One of the biggest advantages of the equalizer is that it is independent of changing environmental conditions. This means that with exposure to changing conditions over time or diverse conditions at diverse remote sites, the equalizer at the remote terminal will automatically adapt to mitigate the effects of distortion.

Mitigating impairments through predistortion

Under predistortion, a filter is placed at the gateway to mitigate the effects of VSAT channel impairments. With a specially designed environment and probing scheme, end-to-end impairments are probed to configure the predistortion at the gateway transmitter. Predistortion can compensate for nonlinear distortion and requires special receivers to estimate channel conditions and provide feedback.

Although predistortion has better power efficiency and is cheaper and simpler to implement compared to equalization, requiring complexity only at the gateway, it cannot adapt to changing environmental conditions if operating conditions are different from probing conditions. This includes tracking of long-term variations due to temperature and aging, as well as short-term variation at the operating point of HPA.

Conclusion

Impairments in VSAT channels can affect the achievable spectral efficiency for a given system architecture and link budget. The Hughes implementation of an equalizer is highly effective in mitigating the effects of VSAT channel impairments. One of the significant advantages of the equalizer implementation is that it is independent of changing environmental conditions. Based on system architecture and operating conditions, either equalization or predistortion may be effective for alleviating the effects of impairments.

Proprietary Statement