Iman Sheshtawy

Professor Habib & Richardson

EAP 507-P01/EAP 508- P02

April 28, 2015

Impairments of Satellite Communication Systems:
The Effect of Noise Parameters on the Antenna of a Satellite Communication System

In a relatively short time, satellite communication systems have become widely used i n the area of telecommunications across the whole world. Through time, the market needs had not stopped only on the provided applications, they have expected more. For this and other reasons, system planners work hard to improve the satellite systems, and provide more applications in a large coverage area to meet the market needs. However, the signal reception still weak in certain cases, for example, the multipath signal propagation sent from a satellite to a mobile receiver, in which the receiver receives multiple signals, or a signal received from transmitter via different paths which causes multi-path interference, or audio mutes especially while driving a car or between buildings. Previous research on satellite communication systems has revealed a set of challenges unique to improve the systems' performance. For example, five articles mentioned in A. Nandra et al. (2008) agreed with the important calculations of the link budget parameters during the planning of such a system. The Link Budget Analysis is used to calculate the gains and the losses throughout the satellite communication system. In a recent case study H. Liu et al. (2013) findings provided some equations and graphs of the back-off parameters, showing how important those parameters, to achieve the required performance for a satellite communications system. Yet, despite the growing body of research related to these challenges, less research has explored practical ways to mitigate such noise impairments in satellite communication systems. The purpose of this review of the literature is to find out how to overcome the signal quality impairments, and how to achieve a better system performance by introducing new antennas with new techniques and the calculations needed for such a system. This literature review was conducted in the IEEE/IET Electronic Library database. Searches were made using the following key terms: satellite communication systems, noise impairments, and satellite link budget. The Search limiters used were date range (1995-2015), books & e-books, peer-reviewed journals, and conference Publications. This literature review is organized as follows. In Section 1, introduces the lack of the antenna products that are needed in order to increase the transition of radio signal, and prevent it from breaking down. In section 2, discusses the interference and the nonlinear impairments, and introduces some approaches to improve the spectral efficiency and the satellite performance. In section 3, indicates the importance of link budget analysis in order to calculate gains and losses in a satellite communication system. The driving question for this research is, how might noise impairments received in the antenna affect the mobile reception of satellite communication system? And how might system planners trade-off between cost and performance of a satellite communication systems in order to improve the mobile reception of such a system?

1. The Challenges and Opportunities of Telecommunications Satellite Applications.

S. Senega et al. (2011) have challenged the signal reception impairments by improving the mobile reception of a digital radio signals of a geostationary satellite. The issue of eliminating noise and audio breakdown due to poor reception was investigated. A fast switching antenna diversity system was used in order to increase the transition of radio signal, and prevent it from breaking down. A scan-phase antenna diversity, in which the diversity function is used totally inside the antenna module (S. Senega et al., 2011, p.262). The difference between both antenna modules is that the Antenna diversity is a high cost hardware, unlike the scan-phase diversity which is considered as low hardware cost. The Antenna diversity prevents audio mutes by using more than one antenna (S. Senega et al., 2011, p.262). Therefore, a scan-phase antenna is preferred because only a single cable is used or enough to connect an antenna module to a standard single arm Satellite Digital Audio Radio Services (SDARS) receiver (S. Senega et al., 2011, p.262). Meanwhile, they were investigating the lack in the current antenna products, and required future antenna products to reach a better performance and meet the market's needs (D. Scouarnec, 2013, p.1412). The current and the future possible telecommunications evolutions are needed to develop the antennas' products to give more applications and improvement for such a business needs. For example, D. Scouarnec et al. (2013) stated some antennas' products that needed to be developed, such as the passive and active antennas, to increase the coverage and the power flexibility, expressing some solution for those types of antennas' products. Also some other antennas parameters, such as reflectors, filters, and accommodation parameters, in which those parameters need to be tuned to "allow a rapid start" (D. Scouarnec et al., 2013, p.1413). In addition to some "niche" products that are used for L band for mobile applications, and UHF (Ultra High Frequency) band for government applications to achieve a global coverage (p.1413). D. Scouarnec et al. (2013) reported some solution for such a limitation to increase the performance of the antenna and increase the economic efficiency, but the complexity of the space segments increases as well (p.1413). Moreover, there is a strong need of additional antennas' applications, such as broadcast, broadband/multibeam, and mobile mission, in which the "trade-offs between performance requirements specifications and accommodation constrains" is needed (D. Scouarnec et al., 2013, p.1412).

2. The Challenges and Opportunities of the Satellite Performance.

Researchers have faced some problems to obtain an advanced receiver processing with a broadband or broadcasting applications to compute the Spectral Efficiency, such as the interference and the nonlinear impairments (time-varying, phase noise, and non-linearities) at the receiver; in which they used a new technique to adopt the receiver so it increases the efficiency of the system. They had a goal to increase the efficiency of the communication system, only if the receiver was able to cope with the interference. They took some considerations and assumptions that may not be applicable to all satellite communication systems. When the interchannel interference (ICI) and the intersymbol interference (ISI) still occur, they applied different approaches in which they relied on for improving the SE based on time packing of adjacent symbols, and reducing the carrier spacing of the adjacent channels. A. Piemontese et al. (2013) explained how to improve the Spectral Efficiency (SE) of nonlinear satellite systems through Time-Frequency (FT) packing and advanced receiver processing. The two different approaches that they considered to detection for nonlinear channel were the use of a detector based on predistortion and memoryless detection, or the advanced detection with memory receivers. Moreover, Z. Guangquan et al. (2013) have found that the real payload, “which performs a specific task and determines the performance of the satellite” (p.216), it is not idealistic to utilize the satellite test process. Due to the fact that satellite’s payload and data transmission system are grammatically high priced, value of position and their lengthy development cycle (Z. Guangquan et al., 2013, p.216). It is required that a new process and developments are adhere to. Therefore, a development of a payload data simulator is necessary to illustrate the duties and transactions of the satellite payload. This way, it is easy to have an accurate test and location. The satellite payload data loader and the superiority of PXI & PXIE creating a closed-loop system make sure that it is working properly (Z. Guangquan et al., 2013, p.220). Moreover, this will have a great impact and an easy process to the satellite test. In other words, Pratt et al. (2003) stated the importance of the trades-off between many factors to reach a better performance with an acceptable cost (p.96). There are some important considerations in order to achieve a better system performance, such as the frequency bands used for such a system, the different types of satellite's orbits, such as LEO (Low Earth Orbit), MEO (Medium Earth Orbit), and GEO (Geostationary Orbit); in which we can collect the requirements needed for each orbit (p.99). The calculations of the link budgets of such a system, and to show how to increase the gain of the antenna and also provide what so-called frequency reuse with respect to the signal impairments are very important for a system planner to get a high performance system. Pratt et al. (2003) stated that "All communication links are designed to meet certain performance objectives" (p.100). One of the most important parameters that has to be measured at the transmitted or received signal carrying the information is the Bit Error Rate (BER) in a digital link, or the Signal-to-Noise Ratio (SNR) in an analog link, in which they are determined by the Carrier-to-Noise Ratio (C/N) at the input of the receiver (p.100). Pratt et al. provided the calculation of the received power from a satellite to an earth station, discussing the use of the flux density, the gain of the antenna, the transmitted and received power, the effective isotropic radiated power, and the path losses (p.103). Moreover, the system noise temperature and the G/T ratio and its calculations are very important to determine how much noise is generated (p.107). Pratt et al. (2003) presented an important example for the calculation of link budget "C-band downlink for earth coverage beam" (p.115), showing the importance of going throughout such calculations for different systems to provide the required performance (p.150).

3. **The Link Budget Analysis.**

Link budget parameters has been viewed as a very important and helpful for the satellite communication systems, so that designers can design a satellite with a high performance and a good quality. With regard to satellite communication system impairments, A. Nandra et al. (2008) have provided the important parameters that help to design a good system, such as the orbital location, the ratio of gain of the receiving antenna of satellite to system noise temperature (G/T = G/T), the standard flux density of the transponder (SFD), the effective isotropic radiated power (EIRP), in addition to the intermodulation products (IM), in which they have included a figure to describe the nonlinearity of the amplifier used by such an antenna (p.148). There are some requirements and variables that are needed to be calculated during the design and the planning of such a system, such as the cost of the antenna and receivers, and the required techniques to determine the parameters used in the earth station and the satellite as well, to provide the performance required. Consistently, there are five articles mentioned in A. Nandra et al. (2008) agreed with the important calculations of the link budget parameters during the planning of such a system. In a study that explored a new method to control the traffic in broadband multibeam satellite communications systems, H. Liu et al. (2013) findings provided some equations and graphs of the back-off parameters, showing how important those parameters, to achieve the required performance for a satellite communications system. Choi et al. (2009), in turn, "proposed a beam allocation and traffic rate control method" (as cited in H. Liu et al., 2013, 1396). This method described the adoption of a uniform back-off parameter with the traffic rate by taking some consideration. Additionally, A. K. Kundu et al. (2013) have illustrated the design of mobile satellite communication antenna called "Parabolic Helix" and the optimization of the link budget to get a better performance (p.1). They have made some calculations that shows the reliability and the effective cost of the system, such as “G/T (the ratio of antenna gain to system noise temperature or a figure of merit), effective isotropic radiated power (EIRP) and C/N (the ratio of carrier power to noise power density)” (p.1). Moreover, they have calculated the uplink and downlink budgets for the selected antenna, in which the results showed that the proposed antenna system is realizable and have “similarity between the gain obtained by simulation and the gain obtained by the calculator which is approximately equal to 16 dB.” (p.6). Relatedly, findings from Pratt et al. (2003) discussed the reliability of the satellite communication systems, and its parameters, showing the link performance that can be measured by those parameters, such as the received carrier power ratio, the noise power spectral density, and the C/N ratio in which the quality of service is determined. Relatively, A. Garcia et al. (1995) have provided some calculations for their case of study to increase the antenna gain. As a result, according to figure (8) (A. Garcia et al., 1995, p.211), it can be observed that “the elevation angle reach some maxima corresponding with the minimal values of the BER” (p.212), which means that the maximum value of an elevation angle is proportional with the minimum value of the Bit Error Rate (BER), which leads to a better coverage.

4. Synthesis: Limitations and Suggestions for Future Research

The review above has identified three factors that have been reported fairly consistently as associated with the adjustment issues of the reception of satellite communication system. However, there are limitations in the literature. As a result, suggestions for future research seem warranted. Initially, future requirements for the antenna products evolutions should reach a better performance and meet the market’s needs. Among the studies examined, the ten articles (A. Piemontese et al., 2013; Z. Guangquan et al., 2013; S. Senega et al., 2011; D. Scouarnec et al., 2013; Pratt et al., 2003; A. Nandra et al., 2008; H. Liu et al., 2013; A. Kumar Kundu et al., 2014;

A. Garcia et al., 1995; C. McLain et al., 2010) required the system planners to go through multiple design and considerations, then compare the results to determine which one is the best for such an application.

5. Conclusion

The purpose of this article was to review literature related to the opportunities and challenges of signal reception in the satellite communication system. As a result, four convergent findings were identified in an effort to answer the research question. These findings can be used in an integrated form to guide the system designers to go through several design and determine the best performance for the communication system. For example, with regard to the link budget analysis, the efficiency of the signal and the performance of the system could be developed to increase the antenna gain, also to improve the signal to noise ratio. Similarly, further work to introduce new antenna product in order to increase the transition of radio signal, and prevent it from breaking down.

References

A. Piemontese et al., "Improving the Spectral Efficiency of Nonlinear Satellite Systems through Time-Frequency Packing and Advanced Receiver Processing", IEEE Transactions on Communications, Vol. 61, pp. 3404-3412, July 2013.

Z. Guangquan et al., "Design and Implementation of Satellite Payload Data Loader", Electronic Measurement & Instruments (ICEMI), 2013 IEEE 11th International Conference, Vol. 1, pp. 216-220, Aug. 2013.

S. Senega et al., "A Fast Switching Antenna Diversity System for Improved Mobile Reception of Digital Radio Signals of a Geostationary Satellite", Antennas and Propagation (EUCAP), Proceedings of the 5th European Conference, Rome, pp. 262-264, Apr. 2011.

D. Scouarnec et al., "Current Antenna Products and Future Evolution Trends for Telecommunication Satellites Application" Antennas and Propagation in Wireless Communications (APWC), IEEE-APS Topical Conference, Torino, pp. 1412-415, Sept. 2013.

Pratt et al., "Satellite Link Design", *Satellite Communications*, 2nd Ed., 2003, ch4, pp. 96-155.

A. Nandra et al., “Optimization of Satellite Link Design”, Southeastcon, IEEE, Huntsville, AL, pp. 147-152, April 2008.

H. Liu et al., “Max-Min Rate Control on Traffic in Broadband Multibeam Satellite Communications Systems”, Communications Letters, IEEE, Vol.17, pp. 1396-1399, May 2013.

A. Kumar Kundu et al., “Designing a Mobile Satellite Communication Antenna and Link Budget Optimization”, Electrical Information and Communication Technology (EICT), International Conference, Khulna, pp. 1-6, Feb. 2014.

C. McLain et al., "Capacity and Coverage Planning for Networks of Small Mobile Terminals in the C and Ku Bands", Military Communications Conference, San Jose, CA, pp. 1526-1532, Oct. 31 2010-Nov. 3 2010.

A. Garcia et al., "Design and Simulation of a Global System of Mobile Communications by Satellite", Digital Satellite Communications, Tenth International Conference, Brighton, vol.1, pp. 208-212 , May 1995.