Telemetry Band Augmentation: An Agenda Item at the Next World Radio Communication Council

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ABSTRACT

One of the significant factors affecting combined operations is the planning, scheduling, and utilisation of telemetry and telecommand spectrum to support next generation platform development and to support operational tests conducted in combined environments (air, land, sea and space). Due to commercial spectrum encroachment and the resultant reallocation legislation, the increasing (flight test) need for real-time data display and analysis is quickly becoming unsupportable in the existing bands.

Several research efforts have increased telemetry efficiency by decreasing the amount of spectrum needed to transmit information. These techniques, promising a two to three fold increase, still can't address the need for future wide-band telemetry, which is growing exponentially.

This has generated a call to look for additional radio frequency spectrum allocations to augment the existing telemetry bands. This need is shared by the international community and has generated an agenda item for the next meeting of the World Radiocommunication Conference (WRC). Due to the international impact of spectrum encroachment on telemetry users, the International Foundation for Telemetering established an information interchange forum, called the International Consortium for Telemetry Spectrum (ICTS), to support this critical requirement. It is necessary that all telemetry users support a positive response to this WRC agenda item to meet the needs of future test programmes.

1.0 TELEMETRY SPECTRUM NEEDS AND LIMITATIONS

Telemetry spectrum is required for the transmission of real-time data from the test vehicle. It allows the testers to conduct safe, effective, and efficient tests by displaying and analysing data in real time. The

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telemetry frequency bands, located between 1400 and 2450 MHz, are vital to both commercial and military flight testing activities.

Telemetry expedites testing. It allows real-time decisions/results that shorten the time required to complete testing, and qualify new products. This results in safer products, reaching the market faster and reduces customer operation and maintenance cost (since they can retire old systems faster) whilst also increasing supplier profits.

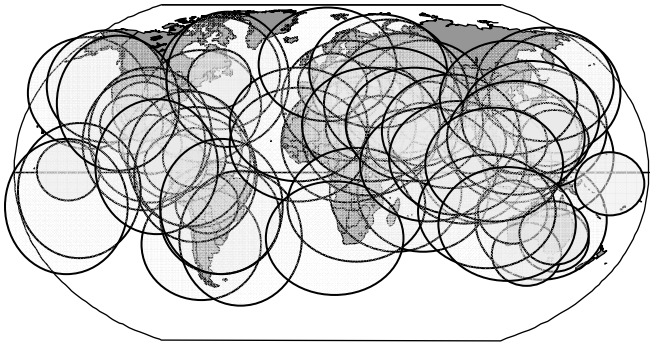

Figure 1: Telemetry Spectrum Usage

Figure 1 shows the approximate telemetry operating areas around the world. The circles represent launch sites, scientific sites, and test and evaluation facilities. There are very few nations that do not have some dependency on telemetering.

However, the existing telemetry bands are heavily sought after by non-aerospace industries for personal communications (e.g., wireless web and cellular telephones) and entertainment (e.g. digital audio / video broadcast) use. The existing telemetry bands, operating at capacity in several regions, are increasingly affected by encroachment from commercial interests. Such encroachment has, in a very short timeframe, markedly reduced the already limited RF spectrum available for aeronautical telemetry.

Spectrum encroachment will continue to have a wide-ranging impact on the aeronautical test community. Many T&E programmes today are operating at a less than optimal test efficiency, due to lack of real-time capability. Missions have been delayed and lost due to lack of sufficient spectrum to schedule activities. This has resulted in increased test programme delays, costs, and project risks. Examples of these impacts were documented in a U.S. National Telecommunication and Information Administration (NTIA) special publication, which quotes impacts to several military projects as a result of RF spectrum limitations. [1].

Telemetry spectrum allocations are being reduced to such an extent that many of the wide-band (high data rate) systems, such as those used in advanced avionics or engines, will not be able to be tested effectively in the existing bands without data transmission limitations. When a tester is forced to reduce the desired amount of real-time data, the flight test programme is negatively affected. The anticipated result is that some establishments will choose to work around the interference (with an increased programme risk). However, some programmes will be forced to stretch out their test schedules as they compete with other projects for Range time in unaffected frequency bands (cost and risk), and some programmes will choose to greatly reduce testing in order to avoid cost and schedule impacts (due to increase technical risks).

2.0 THE NEED FOR WIDE-BAND TELEMETRY

The demand for telemetry spectrum is a direct result of a revolution in aeronautical system technology and the short time-to-market timeframes required by the modern system acquisition cycle. More and more systems are requiring collection of massive amounts of data to meet system test or operational needs.

Figure 2 reflects a survey conducted by the U.S. Advanced Range Telemetry (ARTM) project office [2], which indicates that the data rates for projects using aeronautical telemetry (dots) are growing at an exponential rate (upward arrow). Today, there is not enough RF spectrum available to address this growing need (downward arrow).

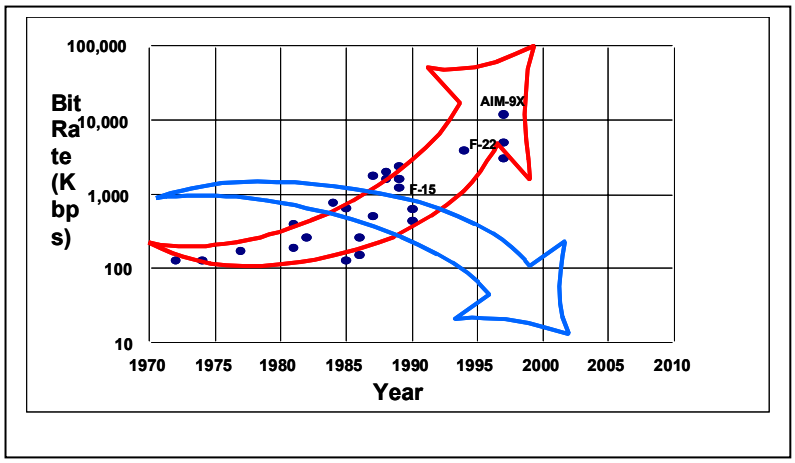

Figure 2: TM demand increasing while supply decreases

Where are these requirements coming from? To effectively and efficiently test these sophisticated systems the tester is drawn to more in-depth analysis (systems are more complex) and a shortened acquisition cycle (do more real-time work to meet schedule and cost constraints). This drives telemetry requirements to ever-higher data rates.

Other points to be considered are:

System Complexity: This drive toward increasing data rates is a direct result of the complexity of the technology in current and planned systems. The tester of complex systems is driven to address expansion in areas such as avionics data transfer rates and integrated wideband sensors.

Modelling and Simulation: To effectively test these systems, the tester must apply new techniques. A revolution in simulation-based acquisitions is driving an increased need for the verification and validation (V&V) of models to reproduce specific environmental conditions and trials geometry's. The ability to fly a simulation and provide real-time correlation to an open-air test activity is a perceived V&V need that will increase the requirement for real-time data.

System of Systems: The flight testers find that they are tasked to evaluate complex, integrated system-of-systems test articles. Many of these systems must be tested in an operationally representative integrated environment. For example, a military aircraft test may require four aircraft attacking four intruder targets. Each test aircraft may currently have two telemetry links in operation. Each missile and target may have a telemetry link. Thus, in one test there may be 12 or more telemetry links. Depending on missile types and test requirements, there could be aggregates of 60-plus Megabits per second passing over the communications links.

The same may be applicable to the testing of commercial products that require integration with existing and other new systems.

In general, an increase in data rate causes an increase in the amount of spectrum occupied by the signal (typically defined as 2.5-3 Hz per bit for proper channel separation). More data at faster rates (more spectrum) are required for these system-of-systems tests.

Time to market. The need for a shorter acquisition cycle drives the need for higher telemetry rates. Typically, as acquisitions are accelerated, the time and budget allocated for test are also trimmed. On past programmes, many organisations have been able to substantially shorten test cycles by conducting more of the analysis and evaluation in real time, thus allowing more tests to be conducted in a shorter time period. Avionics flight test is increasingly relying on real-time imaging data (video and IR). This also allows the tester to be more responsive to anomaly identification and correction, reduces test risk, and increases the safety margins.

3.0 SPECTRUM ENCROACHMENT AND ONGOING MITIGATION TECHNIQUES

While spectrum augmentation may be imminent, it is still too far off (post-2007) to help the telemetry user today. A number of techniques have been, and are being, developed to ameliorate the spectrum encroachment problem pending additional spectrum allocation.

In the U.S. the ARTM project is an ongoing programme to improve the efficiency, reliability, and utility of aeronautical telemetry systems for U.S. DOD test and training ranges. A number of improvements will directly result in the avoidance of increased cost and schedule due to the limited amount of spectrum or unreliable telemetry data links. The ARTM project has conducted research and development into the following:

- More efficient modulation schemes (refer figure 3)
- Equalisation techniques
- Onboard data management
- Antenna diversity experiments
- Advanced antennas
- Data compression

In Europe Airbus Industries has experimented with coded orthogonal frequency division multiplexing (COFDM) to improve telemetry reception. COFDM is a system of modulation well suited to propagation in a high multipath / interference environment and is used extensively in Europe for UHF terrestrial digital television and audio broadcast applications. [3]

While the ARTM and similar projects have indeed contributed significantly to the Telemetry knowledge base, an ongoing programme of science and technology (S&T) projects, funded by the U.S. DOD, will facilitate the augmentation of the current telemetry bands with additional bands between 3 and 30 GHz. Work is presently underway to develop, demonstrate, and evaluate the technology, components, and capabilities, in order to advance telemetry in seven key technical areas:

1. Spectrally efficient bandwidth techniques at super-high frequencies
2. Solid-state technology for high power (5-10W) telemetry transmitters
3. Advanced (narrow or variable beam width directional) antennas
4. Effects of Doppler shift on receiver tracking for coherent receivers
5. Channel characterisation
6. Mitigation techniques for atmospheric attenuation
7. Techniques for overcoming adverse channel effects

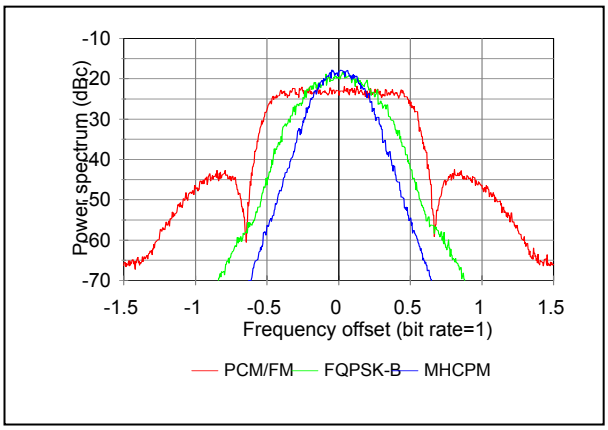

Figure 3: Advances in modulation Techniques

While great strides have been made in spectrum efficiencies internationally, the insatiable demand for real-time data will out-pace the increase in efficiencies.

In *Economic Impacts of Telemetry* [5] C. Kahn presents data showing that the reduction in relative quality of flight-testing can be estimated based on the reduction in telemetry spectrum. Access to the telemetry spectrum is expected to decrease due to mission data rate increases by 98 percent between 1999 and 2022. Figure 4 (from Ms. Kahn's paper) illustrates this forecast.

The figure, based on a data rate growth forecast by Ernst[i], shows the relative level of available spectrum versus demand, using 1999 as the reference year, and assuming that the advanced modulation technique developed by the ARTM programme known as "Tier 1" [see Ernst] is used through 2006. In 2007 the ARTM "Tier 2" modulation technology should become available, improving the capacity of the available spectrum.

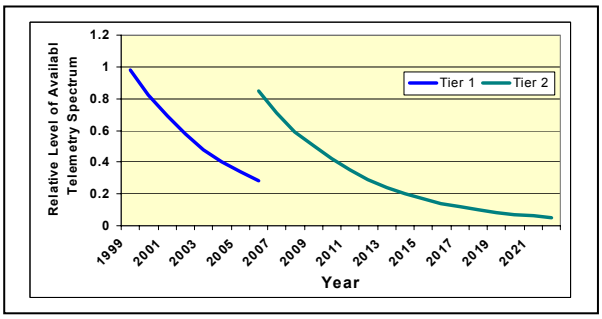

Figure 4: Effect of Advances on Needs

Even with the gains in efficiency obtained from the ARTM Tier 1 and Tier 2 technologies, a single high-data-rate flight test in year 2020 will require 600 MHz of spectrum for telemetry [6]. The improvements described have therefore only postponed the inevitable crisis.

Telemetry is critical to the international aerospace industry because it increases efficiencies and revenues, reduces product cost, decreases time-to-market, and reduces safety risks. The future health of the aeronautical Industry is reliant upon the availability of sufficient telemetry spectrum.[7]

From the mid -1990's the U.S. National Aeronautics and Space Administration (NASA) recognised that they would not have enough telemetry spectrum available to test the many new vehicles that were on the

drawing boards at that time. They proposed that telemetry be permitted in a band somewhere between 3 GHz and 30 GHz. This proposal was eventually accepted for consideration by the International Telecommunications Union (ITU) at WRC-97. The vote on the proposal has been deferred several times and the WRC in 2003 decided (Resolution 230), to include the topic of possible additional spectrum allocations for aeronautical telecommand and telemetry as agenda Item 1.5 for the WRC 2007.

4.0 THE ROAD TO WRC 2007

"To consider spectrum requirements and possible additional spectrum allocations for aeronautical telecommand and high bit-rate aeronautical telemetry, in accordance with Resolution 230 [COM7/5] (WRC-03)"

Agenda Item 1.5 asks that we consider the spectrum required to satisfy justified wideband aeronautical mobile telemetry requirements and associated telecommand above 3 GHz. We are to review, with a view to upgrading to primary, secondary allocations to the mobile service in the frequency range 3-16 GHz for the implementation of wideband aeronautical telemetry and associated telecommand. We are to also consider possible additional allocations to the mobile service, including aeronautical mobile, on a primary basis in the frequency range 3-16 GHz for the implementation of wideband aeronautical telemetry and associated telecommand. Consideration is to be given to designating existing mobile allocations between 16 and 30 GHz for wideband aeronautical telemetry and associated telecommand.

The WRC working parties are asked to conduct, as a matter of urgency, studies to facilitate sharing between aeronautical mobile telemetry and the associated telecommand on the one hand, and existing services on the other hand. The forgoing is a lot to ask in such a short time.

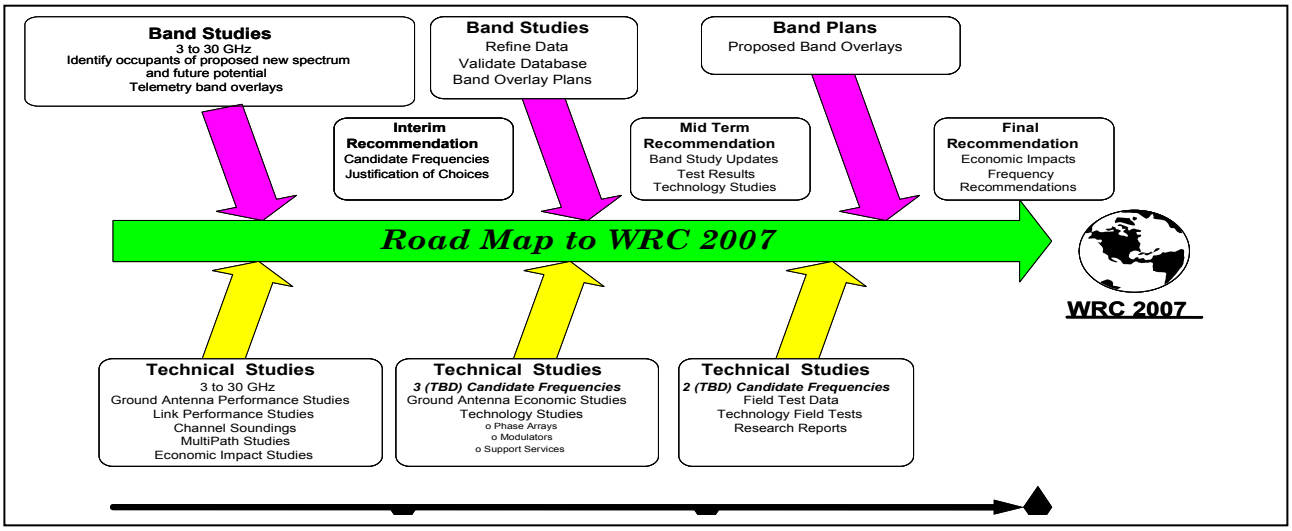

Fig. 5: Roadmap to WRC 2007

Figure 5 outlines a technical map to get the right information to the WRC attendees. draft CPM Report on this subject. A significant amount of this work will be accomplished in the Conference Preparatory Meeting (CPM) and the working parties (WP) established to support the work of the ITU. This item was assigned to International Telecommunications Union (Radio) (ITU(R)) WP 8B. The WP 8B has already held several meetings to prepare the background section for a draft CPM Report on this subject.

The draft CPM report must address:

- Internationalisation
- Global Research
- Harmonisation
- Requirements Validation
- Bandwidth
- Identify Candidate Bands
- How are they currently used?
- Identify incumbents/compatibility issues

To be successful, we recommend that all those effected by aeronautical telemetry (suppliers of products and buyers) support their national administrations in:

- Validating the amount of spectrum needed
- Selection of candidate bands
- Co-ordinating their position with other countries

5.0 THE INTERNATIONAL CONSORTIUM FOR TELEMETRY SPECTRUM

Spectrum encroachment has become an international issue as a result of increased commercial interest. The **International Consortium for Telemetry Spectrum** (ICTS) is chartered under the sponsorship of the International Foundation for Telemetering (IFT). The IFT exercises oversight responsibility and authority of this consortium and provides administrative, policy, and programmatic approval. The ICTS was formed in response to the need for an international coalition of telemetry practitioners who share a common goal of ensuring the availability of electromagnetic spectrum for telemetering. Under no circumstances shall the issues within their respective organisations. ICTS publish, present, or in any other way represent a position on spectrum issues. However, the information shared within the ICTS will enable telemetry practitioners to effectively respond to spectrum

The ICTS maintains a database that contains a list of frequency allocations assigned to individual nations and regions for telemetering. It also publicises to members of the ICTS any planned or proposed changes to spectrum allocations affecting telemetering. It gathers and disseminates information to ICTS members on spectrum related issues.

The ICTS is an international organisation comprising telemetry practitioners from government, industry, and academia. Regional co-ordinators representing the three regions defined by the ITU: Region 1 - Europe, and Africa; Region 2 - Americas; Region 3 - Asia and Oceania. The consortium shall be open to individuals or organisations that support the goals of the ICTS and have a business or professional stake in the use of the telemetry spectrum. An overview of the history of the consortium and an expression of the importance and benefit for information exchange, together with meeting announcements, minutes, and other information is posted on the ICTS web site [8].

5.1 ICTS plans

Telemetry spectrum is vital to aeronautical sciences. The international telemetry community needs to take the necessary steps to be proactive in the defence, development, and research of telemetry systems. To not address all three will prevent the advancement of flight sciences and operation of aeronautical systems.

Protect: We must be able to defend existing spectrum allocations from further encroachment. This encroachment can take many forms from commercial interference concerns from personal communication services and digital audio broadcasters to threat of spectrum reassignment. We must be able to educate our governments of this vital resource to ensure its protection. Through the ICTS, we can exchange the data needed to equip each member to provide this education. By making reports, studies, threat information, and technical data available to the members, a more co-ordinated proactive approach is possible.

Promote: New methods are needed to improve spectrum efficiency. This can take the form of new modulation techniques, antenna technologies, and frequency scheduling and de-conflicting, and other techniques. In the US, ARTM, iNET, and other projects are sponsoring these efforts at about $4 to 5M U.S. per year. Other research efforts are underway at many universities and laboratories. The sharing of the results from these efforts is also a benefit of ICTS membership.

Research: To accommodate the current and emerging wide-band telemetry needed for future aeronautical system requirements we need to look outside the existing spectrum. In the U.S., the DOD and NASA have driven research into methods to improve our existing efficiencies (e.g., higher order modulation techniques, antennas, and networks) that can result in a 2:1 or greater increase. These developments will not keep pace with near-term real-time data growth or the encroachment on existing bands. We need to plan further into the future with expanded capabilities to support wide-band telemetry applications.

5.2 Current Activities within the ICTS

Special Topics: At each of the ICTS meetings, time is allocated for special topics that affect the telemetry community. Presentations in the past have covered the ARTM project, Airbus COFDM modulation results, interference issues (unlicensed devices and digital audio broadcast satellites), and telemetry usage in member nations.

Members and invited guests keep the ICTS current on the status of the telemetry research and development. Projects such as ARTM and iNET and other efforts are common meeting topics. Currently the U.S. is a ‘hot spot’ for spectrum augmentation research. A spectrum augmentation initiative is being funded through the DoD’s Science and Technology programme described earlier. The purpose of the spectrum augmentation initiative is to investigate technology components and capabilities that will enable flight and ground test telemetry operation in the SHF band. The frequency bands currently under consideration are 4.4-4.9 GHz, 5,4-4,9 GHz and 7,125-8,125 GHz.

Publicity: Publicity is a significant part of the ICTS mission. Getting the information out is difficult useless you know who will need the information. The ICTS Region I office, with its SEE secretariat in Paris, publishes the consortium’s regular e-newsletter.

Regular ICTS representation at various forums and conferences is a desired goal in order to inform to those affected by telemetry issues. Conferences such as those sponsored by International Test and Evaluation Association (ITEA), Systems Engineering/Test and Evaluation Conference (SETE), European Telemetry Conference (ETC), International Telemetry Conference (ITC), European Test and Telemetry Conference (ETTC), and others has helped to present the ICTS concerns to engineers, scientists, and managers. Attendance by ICTS members at these conferences help to publicise the telemetry encroachment issues and advertise the ICTS. The next ICTS meeting will be at the ETTC in Toulouse, France in June 2005.[9]

WRC 2007 Campaign: Getting the ICTS membership ready for WRC 2007 is currently the major effort for the ICTS.

Resolution 230, described above, proposes allowing telemetry in two bands, one below 16 GHz and one above 16 GHz. It also includes the phrase “associated telecommand”. The text states that it is to be

implemented "in accordance with the Resolution," and makes it clear that telecommand is to be "associated with" telemetry.

The ICTS has undertaken a number of activities to help its members prepare for WRC-07. These effects include.

Global Use Matrix: ICTS Region II maintains the Global Telemetry Use Matrix for the ICTS. A recent addition to this database is China. The Global Use Matrix details how each country uses the telemetry bands. This is an on-going data gathering effort for the use of ICTS members to consider when formulating their position on band sharing proposals associated with WRC 2007 Resolution 230.

Economic Impact: One of the main messages the ICTS is trying to deliver to the community is the economic value of telemetry to national economies. As discussed earlier, this message is vital to gaining the needed support from ITU member countries. ICTS Working Group 1 has sponsored a report on the economic benefits of aeronautical telemetry, which was presented at the 10th ICTS meeting. This report allows ICTS members to communicate the importance of telemetry to their national authorities.

Publicity: As a source of information to assist members in making informed decisions, we must first attract members. Current ICTS members represent only a few countries. Countries with significant economic concerns that are not currently represented include: Italy, Denmark, Spain, Ireland, Russia, Canada, Mexico, Argentina, China, Japan, Singapore, Malaysia, India, and South Africa. The ICTS is looking for methods to reach impacted companies and customers in these countries. In the ITU, every country has one vote. The countries that have adequate data for an informed position will make a wise decision. The goal of the ICTS is to reach those communities with that data.

6.0 REFERENCES

[1] Spectrum Reallocation Study as Required by the Balanced Budget Act of 1997, Special Publication 98-36 NTIA

[2] Advanced Range Telemetry (ARTM) Project. www.cteip.osd.mil

[3] www.dtg.org.uk

[4] Dan Skelley; Integrated Network-Enhanced Telemetry, Proc. of the ITC 2003, October 2003, San Diego,CA.

[5] Carolyn Kahn; Economic Impact of Telemetry, The MITRE Corporation, McLean, VA, March 2004

[6] Darrell Ernst; *The Growth of Data Rates for Aeronautical Telemetering and the Implications for the Radio Spectrum*, The MITRE Corporation, McLean, VA, May 2004

[7] T.Chalfant, D. Ernst; *Telemetry band augmentation*, Proc RAeS 5th T&E International Aerospace forum, London, England, July 2004

[8] www.telemetry.org

[9] www.ettc2005.org