InterConnect Communications
A Telcordia Technologies Company

Procurement of Spectrum Management and Monitoring Systems

Considerations for Maximising Investment Return

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It can be argued that the radio spectrum has become to today's information and communications technology (ICT) sector what coal was to the industrial revolution of the 19th Century. The long-established use of the radio spectrum by the broadcasting, defence, emergency services plus aeronautical and maritime sectors is well recognised. However, with liberalisation and competition in the telecommunications sector, the demands for access to radio spectrum have grown enormously in recent years. Spectrum is now a key resource in the implementation of networks, in the efficient and rapid delivery of services and it is THE essential ingredient in the provision of any service requiring mobility.

In contrast to the measured pace of the industrial revolution, rapid changes in technologies affecting spectrum use challenge policy makers and regulators in achieving their objectives of ensuring allocation of spectrum in the public interest and efficient spectrum use. For example, current and planned deployment of digital technologies in traditionally analogue areas offers significant opportunities for policy change. Facilitating spectrum access for services based on new technologies at the same time as encouraging investment by offering reasonable security of tenure requires ongoing balance.

At the same time as technology developments, new regulatory approaches have impacted spectrum policy. Around the world, efficiency of use has been pursued through market-driven allocation processes, together with trading in spectrum. Fees paid for access to spectrum around the world bare testimony to the value placed on spectrum by those seeking access to it. Not only were huge licence fees paid in many countries for spectrum allocated to Third Generation Mobile (3G) services but recent auctions continue the trend. For example, the recent auction of just 2 times 3.3 MHz of low-power GSM spectrum in the UK generated £3.8 million in fees for spectrum which will be accessed/shared equally by all parties, with no exclusive usage rights. One of the parties alone paid over £1.5 million for the right to share access to this spectrum with the other 11 bidders[1].

However, the strong demand and high value associated with spectrum together with evolving spectrum policy places enormous pressures on spectrum managers to resolve the many conflicting access demands which will inevitably arise and to then generate accurate frequency assignments in spectrum which is free from harmful interference. Having paid so handsomely, a licensee is unlikely to accept interference from squatters in or neighbours to their precious spectrum!

Not only must the 'quality' of the spectrum managers' work be spot-on, they will also be required to make difficult or complex decisions and act quickly under pressures

1 http://www.ofcom.org.uk/radiocomms/spectrumawards/completedawards/award_1781/notices/030506.pdf

exerted by the commercial sectors. Simple or basic assignment tools, processes and monitoring equipment are no longer up to the job in this dynamic new world; spectrum managers must turn to bespoke state-of-the-art spectrum management and monitoring systems if they are to have any chance of servicing the needs of the spectrum using communities.

The following sections are offered to provide an overview of the procurement process. Discussion is not intended to be exhaustive, but to rather to raise awareness of some of the key issues that will be faced and skills required to ensure a successful procurement.

Initial Considerations

Having recognised the need to invest in the appropriate tools to enable the spectrum management organisation to provide an efficient and effective service, the first step will be to create a design for the system to be implemented and to arrive at a budget. Or should that be, to set a budget and then to design the most effective system available for the budget? Which came first – the chicken or the egg?! It is inevitable that there will be some iteration of both the design and budget before the expectations of both spectrum managers and those controlling finance and budgets are met.

Nevertheless, at this stage of the process there are steps which can be taken to ensure a satisfactory outcome; those responsible for the design should familiarise themselves with what is available on the market and the pros and cons of the different approaches and philosophies adopted by the various suppliers. Visits to see installations implemented by the various suppliers will also provide the opportunity to talk to purchasers who are often keen to share their first-hand experience of the process.

All parties must realise that funds should not only cover the initial capital outlay of system purchase and implementation but also training needs, spares, plus comprehensive warrantee and maintenance agreements - many of which may be annually re-occurring costs.

Further, the system need not be implemented in one go. The design could be established with a roll-out plan over a number of years. In this case, it is best to launch a single tender with a phased implementation schedule and to make subsequent phases conditional on the successful delivery of preceding phase(s). This approach has many benefits including:

- Reduced overheads compared with running a number of tender processes serially;
- Greater certainty that the system will be implemented in full as the budget required for all phases could be assigned to the whole project at the outset;
- A contract with a single supplier reduces the risks of incompatibility between systems delivered at each phase; and
- A single tender enables the purchaser to benefit from economies of scale, resulting in lower costs.

It is vital that both the engineers who are designing and who will use the system and management, as well as those who control the budgets, are realistic about what is needed to provide an effective spectrum management service and how much it is reasonable to spend on such a system. There is sometimes a tendency on the part of engineers to get over-enthusiastic and carried away at the thought of the technical possibilities available, nothing short of the very latest and absolute state of the art being acceptable. Conversely, budget controllers may not appreciate the sums of money required or the full benefits which a well-conceived and appropriately specified system will bring.

Clearly, the cost of the system will be a major factor to be considered in the design. In budgeting, it will be necessary to consider costs from at least the following:

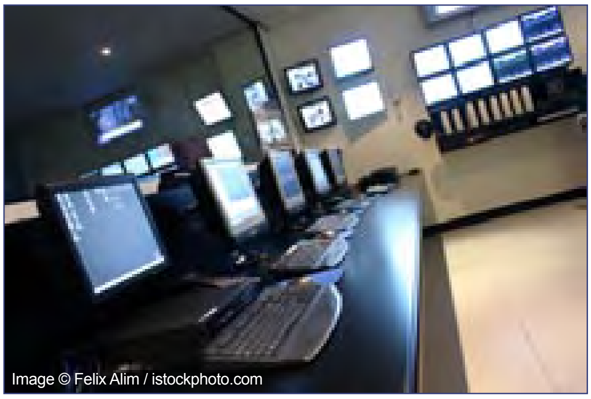
- Specialist spectrum management hardware and software systems;
- Standard office IT equipment and software;
- Office accommodation;
- Costs for gathering and cleansing licensing data, plus conversion into a format suitable for loading into the new database;
- Obtaining and preparing land suitable for installation of fixed monitoring stations - especially if larger High Frequency (HF) direction-finding antennas are required;
- Buildings or containers for housing fixed mobile stations;
- Wide-area network (WAN) equipment for interconnecting the system;
- Masts and civil engineering works during installation of fixed stations;
- Vehicles for mobile stations;
- Warrantee costs;
- Maintenance contract;
- Training of staff (both initial and repeat/ongoing training needs)

- Staff time consumed by the project (will there be a need to assign staff permanently to the project?); and
- Travel expenses of staff associated with training and possibly acceptance testing at the supplier's premises.

Of course the major cost will be that of the specialist hardware and software, and the major part of this will be the components associated with the monitoring function. Therefore the cost of the system will be largely determined by the quantity of monitoring equipment required – and this will be a function of how much of the country is to be covered with fixed monitoring stations.

Design

A spectrum management system will consist of two closely-linked sub-systems: the licensing sub-system and the monitoring sub-system. It will be necessary to design and specify each separately and also to define and specify how they will be interconnected.



At the heart of the licensing sub-system will be a database of frequency assignments - the national frequency register, and the national frequency allocation table (NFAT). Peripheral to this will be various applications (for example propagation analysis and planning tools) which access and process data from the database and which also write data to the database.

In specifying the database it may be necessary to define the type of operating system as well as the size of the database and the form in which data is to be stored. Then the various applications which interact with the database will need to be specified. These will include:

- Processing of assignment requests and the identification of suitable frequencies;
- Various propagation models;
- Coordination request generation;
- Generation of spectrum licences;
- Invoice generation and payment receipts;
- Maps and geographic information systems (terrain data etc.);
- A means of making licensing data available to the monitoring sub-system.

ITU-R Recommendation SM.1370 on design guidelines for advanced automated spectrum management systems is useful in this respect.

The IT aspects will also require careful consideration, including the number of users that the system should support as this will drive the need for licences to use the database and software applications, as well as the requirements for workstations, printers, scanners etc. Vitally important will be the need to keep the information in the database both secure and free from inaccuracies or corruption - this will impact the design of the LAN and any procedures for accessing data or uploading data to the database. It is reasonable to expect the supplier to customise its offering to take account of working practices and forms etc. used by the purchaser, however, it should be remembered that this activity will also consume budget which, just like radio spectrum, is likely to be in limited supply!

By contrast, the purpose of the monitoring sub-system will be to support the implementation of licensing policies through, for example:

- Verifying the presence of and then locating illegal spectrum users;
- Gathering data on illegal spectrum use to support enforcement actions;
- Measuring spectrum emissions to verify the accuracy of assignment and planning activities;
- Investigating interference complaints;
- Carrying out inspections of installations, either before switch-on, or as part of ongoing inspection campaigns;
- Carrying out campaigns to verify actual spectrum usage in support of assignment activities (for example channel occupancy measurements in areas of congestion or spectrum shortage to identify patterns of usage and possible free spectrum).

This will be achieved by establishing a network of monitoring stations with the capabilities to measure and direction-find transmissions over various bands as required. These stations may be fixed, mobile, transportable or portable.

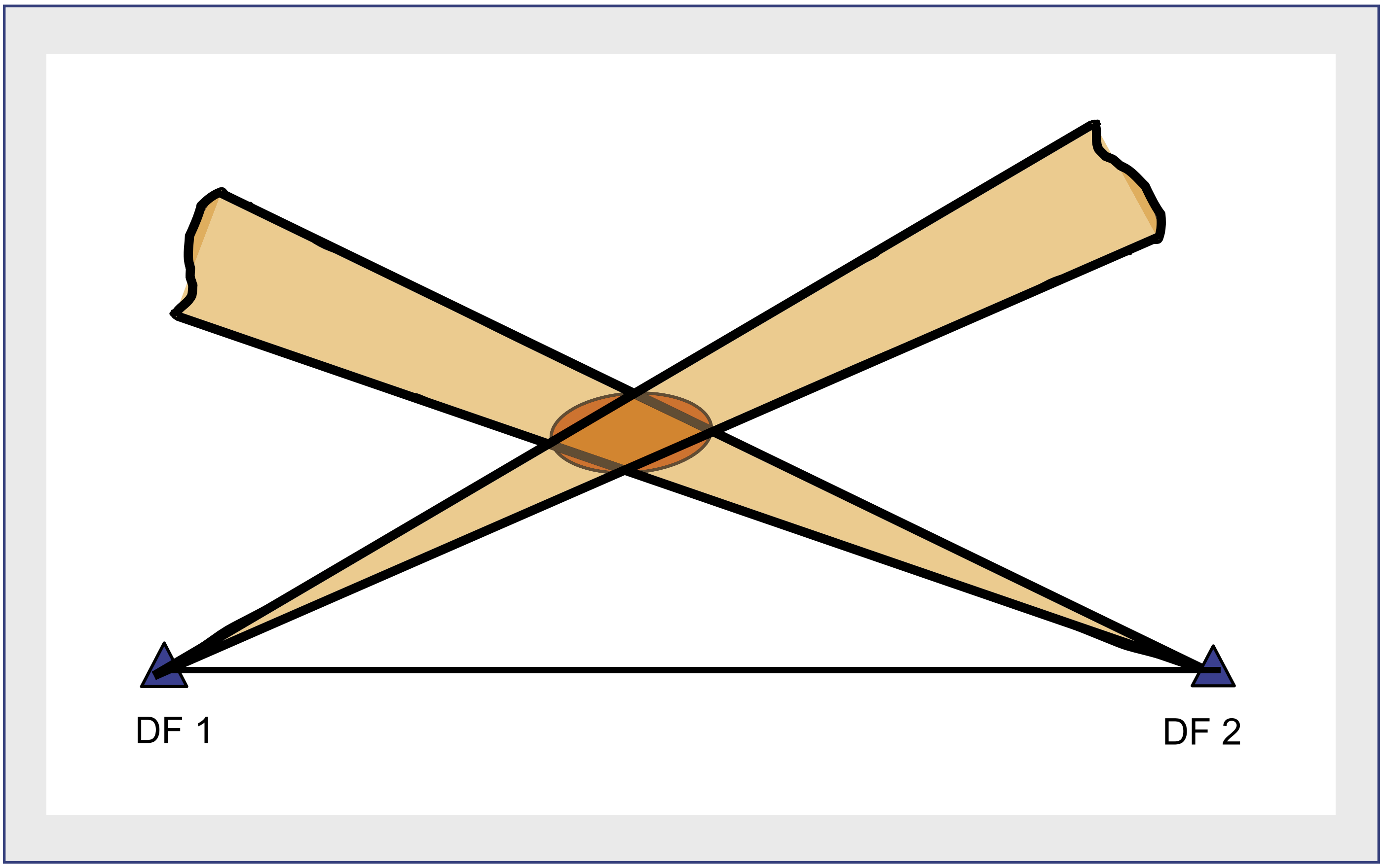

Image © Rafa Irusta / istockphoto.com

The costs of mobile and fixed stations are not that different when the costs of civil works and shelters etc are taken into account (ignoring the costs of land acquisition). It will, however, be necessary to carefully consider the trade-off between fixed and mobile stations in achieving the desired coverage and response time:

- Fixed stations can be unmanned and remotely controlled, thus enabling measurements to be made at very short notice in the areas served by the fixed stations. However, it is unlikely to be economically viable to set out to cover the entire geographic area of a country with fixed stations – especially those areas where spectrum use is low; whereas
- Mobile monitoring stations can be moved about as required and thus can achieve full geographic coverage, albeit, with a reduced response time. Further, a mobile monitoring station will need at least one member of staff to drive plus a further member of staff if measurements are to be taken manually on the move – thus the staffing requirements increase in direct proportion to the number of mobile stations in the system.

There are other factors to consider in this trade-off. Typically, fixed stations have better antenna installations (taller masts, capable of supporting better antennas or much larger HF direction-finding antennas on the ground), thus the area of coverage of a fixed station (from a given location) is greater than for a mobile station and also the accuracy of direction finding from a properly specified fixed station will exceed that of a mobile station. Transportable stations, however, are now very compact and can be quickly and easily set up in any (secure) location. They therefore provide yet another possible compromise – they can be operated remotely like an unmanned fixed station, and when required can be easily moved to another fixed location. Whilst some compromises do remain regarding antennas, it is possible to establish high quality antenna sites without any monitoring hardware and then simply move the transportable systems from site to site as required.

There are also a number of considerations to be taken into account in locating the source of emissions. Generally, a single fixed station can only identify the direction of a signal (its bearing relative to the location of the station), thus it cannot actually locate the position of the source. A second bearing is required and through a process known as triangulation, the approximate location of the source of an emission can be determined. This process is illustrated overleaf:

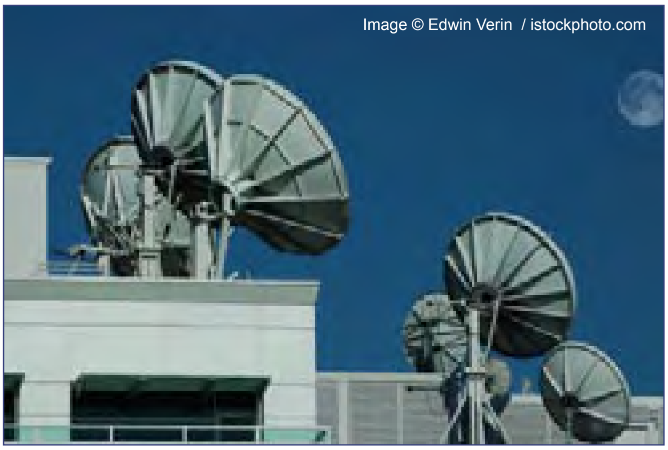


The uncertainty in each bearing measurement gives rise to an area within which the source of the emission will be located. Clearly, both the quality of the direction finding systems (measurement accuracy) and the geometry arising from the location of the two direction finding systems relative to the emission source will determine the accuracy with which the location of the source can be determined. In the above example, the geometry for maximum accuracy would be achieved when the two bearings are perpendicular to each other (i.e. cross at 90 degrees). Increasing the number of bearing measurements available (by increasing the number of stations) will also enhance the accuracy.

Clearly, the above consideration of requirements for direction finding also has a significant impact on the number of stations required and - of course - on the cost of the system. As before, mobile stations can be used to good effect: a single mobile station could take a bearing at location 1 and then move on to location 2 to take another bearing (and also to obtain further bearings at other locations as required). It is then a simple matter of superimposing these bearings on a map to identify the possible location of the source (software tools exist to do this automatically). Of course this approach is only effective if the source is known to be stationary!

Alternatively, a single mobile station could be used to 'home-in' on the source by using a sophisticated set of displays which show the direction of the signal source relative to the location of the mobile station.

There is a further option which can be considered for HF direction finding: Single Station Location (SSL) functionality. SSL functionality relies on the fact that some HF frequencies are reflected by the ionosphere. The use of complex geometry then enables the location of a source to be identified by a single direction finding station which is capable of measuring both the bearing of the signal and its angle of elevation. The accuracy of such a system is highly dependant on various assumptions regarding the behaviour of the ionosphere and accurate data on the height of the ionosphere. A very large field is required to accommodate the complex composite antenna. However, such stations can be used to great effect and are certainly worth considering at the design phase if HF communications are a priority.



Finally, portable monitoring systems are essential for SHF measurement and monitoring and a useful tool in locating the source of transmissions in dense urban areas.

Specification

Having established and documented the design, it will then be necessary to unambiguously define the performance parameters for the system and its various components, including but not limited to the following:

- Generic system features - software and security;
- IT hardware requirements - LAN and WAN, workstations, printers, scanners, database, geographical information systems (GIS) etc;
- Software - database management, GIS, assignment, application processing, administration etc;
- Direction finding functionality -frequency ranges, signal strength, bearing accuracy, speed etc;
- Signal characterisation functionality - frequency range and resolution, signal strength, field strength, demodulation, noise etc;
- Band occupancy measurement - signal resolution, measurement rate, scan table size etc;
- Specific requirements for fixed stations - mast heights, equipment shelters, antennas, power supplies etc;
- Specific requirements for mobile stations - vehicle requirements, communications, generators, servicing etc;

- Training requirements - subject matter, number of staff, duration, location etc; and
- Documentation - scope, language, format etc.

The specification should focus on the required performance rather than be prescriptive about how the performance is to be achieved; the purchaser should not allow itself to accept any responsibility for the final performance of the system by prescribing approaches or technologies which may have limitations associated with them, or which limit the options available to suppliers to achieve the required performance. ITU recommendations are a well established and excellent basis for defining the performance of the many aspects and functions of the system. The core set of requirements should be built around the *Spectrum Monitoring Handbook, 2002* and the following ITU-R Recommendations:

- SM.1370: advanced licensing sub-system
- SM.1598: direction finding and location determination
- SM. 854-1: direction finding and location determination
- SM. 1053: direction finding and location determination
- SM. 1269: direction finding and location determination
- SM. 377-3: frequency measurement
- SM. 378-6: field strength measurement
- SM. 443-2: bandwidth measurement
- SM. 1052 and 1600: signal identification
- SM. 182-4 and 1536: occupancy measurement
- SM. 1537 and 1370: signal characterisation

Tender Dossier

The tender dossier will define the various administrative, commercial and contractual aspects of the tender process. Clearly it will be influenced by local procurement regulations and, possibly, the procurement regulations of any external funding institution (for example, the World Bank).

It is vitally important to give clear and unambiguous instructions to bidders on the process to be followed, including, but not limited to:

- Any opportunities for clarifications to be requested by bidders, either in writing and or at a pre-bid conference;
- The bid submission details: time, date and address;
- Requirements to provide a bid bond – the value of which could be set at a percentage of the price of the offer;
- The presentation, format and quantity requirements for the bid;
- The procedure to be followed in evaluating bids and selecting a winner; and
- A draft of the contract which the successful supplier will be required to sign.

It is good practice to require separately packaged technical and financial offers; the financial offers being kept sealed until the technical evaluation has been completed. In this way the technical evaluation will not be influenced by knowledge of bid prices.

There are two basic approaches to the evaluation of technical offers: the simplest is to seek absolute compliance with all clauses of the technical specification and only those offers which are fully compliant will qualify for evaluation of the financial offer. As an alternative, it is possible to award points for the degree of compliance achieved and, as a further degree of sophistication, different areas of functionality can be weighted more heavily than others, such that the final total score for a technical offer is most influenced by the degree of compliance achieved in the those areas of performance considered most important. A minimum score would need to be achieved if an offer is to qualify for evaluation of the financial offer. This latter approach, however, should not be adopted lightly as:

- The specification should be a statement of the minimum level of performance which is required – thus partial compliance is not acceptable;
- Awarding scores for partial compliance adds a level of subjectivity which is not desirable; and
- The approach would give the supplier's bid precedence over the technical specification in the resulting contract – this is not desirable.

Having established which offers have qualified for the evaluation of the financial offers, it will then be necessary to establish that all bidders have bid on a like-for-like basis. This will include establishing that all the quantities are correct and that the arithmetic of each offer is accurate plus the reduction of recurrent costs to net present values. It will then be possible to establish which offer is most financially advantageous.

In the event that the technical evaluation was to establish full compliance with the technical specification, it is clear that only fully compliant offers would have qualified for the financial evaluation, thus the contract would be awarded to the bid with the most advantageous financial offer.

If, however, scores have been awarded to indicate the relative merits of the technical offer, it will then be necessary to establish a means of awarding scores to the financial offers. This might be 100% of the marks available to the most financially advantageous offer, and then fewer marks to the other offers in proportion to the relative prices. The relative importance of the scores awarded to the technical and financial evaluations can be reflected by weighting multipliers which are applied to each score before they are added together; the winner being the bid with the highest combined score. As discussed above, it does appear that this is an unnecessarily complicated process.

As the tender dossier will have included a draft contract which the bidder was required to acknowledge was acceptable, the process of concluding the contract with the supplier should not prove too arduous. Further, the bid bond would be forfeited in the event that the selected supplier subsequently failed to sign a contract. The bid bond can be replaced with a performance bond after contract signature with an adjustment in value if necessary. Nevertheless, it is important at the contracting stage to ensure that the contract is clear in a number of aspects, including but not limited to:

- The identity of the supplier with the contractual liability to deliver (especially important in the event that two companies cooperated in a joint bid);
- The responsibilities of the various parties to the contract;
- The order of precedence of supporting documentation;
- Delivery terms and quantities; and
- Payment schedule and terms.

Payment terms are worthy of special consideration. The adoption of an achievement (milestone) based payment schedule links payments to delivery against the contract. However, there will also be a need for an advance payment and a final payment:

- The advance payment should be sufficient to support the supplier to fund the production of the equipment; whereas
- The final payment (together with performance bond) should also be large enough to keep the supplier motivated to deliver according to the contract (in terms of quality and schedule).

Implementation

It is important that the purchaser realises that it too will have obligations under the contract to support the timely implementation of the system. Such obligations will include achieving the following in accordance with the agreed implementation schedule and contract:

- The sign-off of the system design and acceptance test procedures;
- Providing complete licensing data to enable the supplier to populate the database;
- Making available suitable sites for the installation of fixed monitoring stations;
- Making staff available for training;
- Making the required staff available to carry out acceptance testing; and
- Making payments to the supplier.

The purchaser needs to adhere firmly to its contractual obligations so as to give the supplier every opportunity to honour its obligations under the supply contract; this in turn will keep the supplier focused on honouring its contractual commitments.

Conclusion

The procurement of a spectrum management system requires significant forethought and pre-planning if the system is to meet all its intended requirements and permit the effective management of the national spectrum resource. Perhaps more critically, the procurement process demands the input of skills from many disciplines, notably technical, financial, project management, commercial and legal, plus an understanding of how such systems are used by regulators and administrations in other countries. Last but not least, those in charge of the procurement process must posess the ability to combine and manage these sometimes disparate attributes successfully so as to assure the desired outcome.

InterConnect Communications

InterConnect Communications is a wholly-owned subsidiary of Telcordia Technologies Inc., based in the United Kingdom, and a leading provider of consultancy services on spectrum and wireless technology issues.

InterConnect has over 20 years experience in managing the radio spectrum at international, national and local levels, and has evaluated, specified, procured and implemented spectrum management and monitoring systems for all size of regulator and administration in countries across the globe. InterConnect has not just worked with numerous organisations to implement such systems but is recognised in its own right as one of the world's leading independent experts, with knowledge of the capabilities of all manufacturers in the field. We have supported the procurement of a wide range of spectrum management (and monitoring) systems using national and World Bank procurement rules.

For more details of InterConnect's radio spectrum services, please visit http://www.icc-uk.com/spectrum.php or e-mail spectrum@icc-uk.com

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