A Novel Approach to Satellite Digital Audio Broadcasting for Australia

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Abstract

A novel method of using the Globalstar LEO constellation to provide 25 channels of digital-quality, audio broadcasting (DAB) to vehicles and homes throughout Australia is described. The low-cost approach will attract broadcasters who want to reach listeners throughout Australia especially in areas of low population density. By adaption of existing satellite radios, transmission systems and the agreements to use Globalstar constellation and ground station equipment, a nationwide broadcast system is feasible. This paper explores some of the technical, regulatory and business factors that will affect the adoption, and drive business success. A conceptual economic model is used to forecast revenues to show that a profitable business is possible,and replacement of the current satellites with ones tailored for SDARS is discussed. Options of obtaining program source material are summarized.

1.0 Satellite Radio Broadcasting in the USA

In 1997, the Federal Communication Commission issued its Report and Order granting two companies; CD Radio and American Mobile Radio Corporation (AMRC) the right to use 12.5MHz of spectrum in the band 2310-2360MHz for Satellite Digital Audio Radio Services (SDARS), including nationwide use of terrestrial repeaters [1].

Since then, Sirius Satellite Radio (previously CD Radio) and XM Satellite Radio (previously AMRC) have launched high-powered satellites, built ground stations, national broadcast studios in New York and Washington DC, and assembled extensive music libraries. The total cost - an estimated $1billion [2], [3]. They have recruited experts from the recording, broadcast and entertainment industries to create a completely different listening experience for the subscriber.

Both service providers are offering 100 channels of music, news, sports and talk radio, across America, for about $10/month. Audio quality has been rated close to CD quality. Sirius are using Lucent's perceptual audio codec SPACv4 and a statistical multiplexing method named, Splex. While XM are now using CT-aacPlus with Neural Audio's pre-processing prior to transmission.

Aftermarket car and home receivers are now available nationwide, and prices have already fallen to around $200. Both companies have agreements with automobile manufacturers to supply new cars with an SDARS receiver option.

XM and Sirius satellite radio offered their services to a limited market initially, to test advertising & marketing strategies, measure quality of service, and to prepare the terrestrial repeater networks. XM is ahead of Sirius in its launch date by approximately 5 months, and to date, has succeeded in securing more than 136,500 subscribers in just 9 months from the date of launch [4], exceeding the company's own targets -see Figure 1.

XM's target is to reach 350,000 subscribers by the end of this year, and the fact that STM Microelectronics, the manufacturer of the radio chipsets announced on April 11 that it had shipped 355,000 radio chips to date, supporting the this target.

Skeptics have stated that the demand is a result of an on-rush of early, techie-type enthusiastic adopters, but in a recent radio interview [5], senior executives of both Sirius and XM Satellite, said that their analysis of the customers shows that a broad range of people are being attracted.

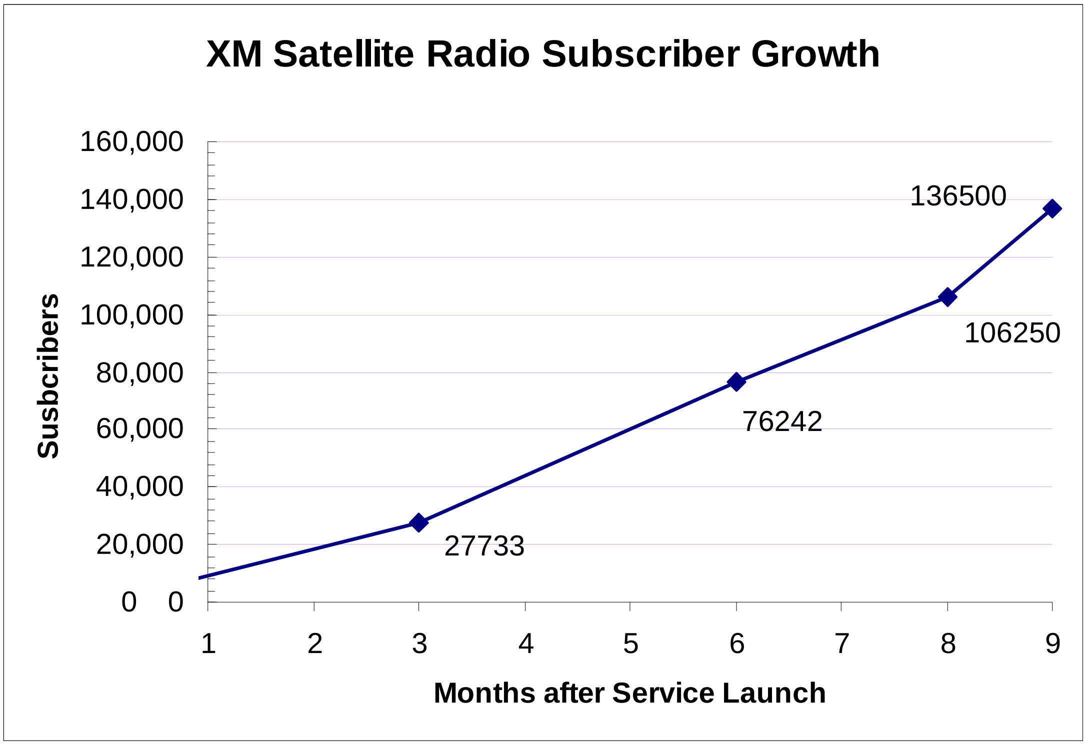

FIGURE 1. XM Satellite Radio Subscriber Growth (Complied from SEC reports and press releases)

According to XM satellite radio, "during the initial 60-day period following our national launch, we exceeded 30,000 subscribers, which represents a faster adoption rate than for any other consumer audio product introduced over the past 20 years, including CD and DVD players" [6].

On February 14, 2002 the second service provider Sirius Satellite Radio launched its service in seven states, and continued a progressive roll-out, providing coverage to all states this month. Using a constellation of 3 satellites (2 always active over the USA) in a highly elliptical orbit, this system is arguably technically superior, providing the advantage of a high elevation angle (>60 degrees) to all users in the desired service area, thus minimizing likelihood of path blockage and multipath propagation effects [7]. The service which is priced at $12.95 per month provides similar programming to XM Satellite but with fewer advertisements - an appealing factor for many. Since its initial launch there is insufficient public data to compile adoption rate curves, but this service is expected to match or exceed XM satellite radio adoption rates. Sirius Radios are claimed to be lower cost, but this price differential will most likely disappear as mass production economics begin to apply. Both systems employ simultaneous frequency, time and path diversity by using at least 2 satellites and numerous terrestrial repeaters, to provide coverage in areas unreachable by satellite signals, Sirius requires fewer repeaters due to its much higher elevation angles.

Five years after the FCC commissioner Susan Ness first commented that terrestrial digital radio was not getting off the ground and that Satellite Radio should be given a chance, SDARS licensees have not only designed, built and deployed infrastructure years ahead of its terrestrial rivals, but they have developed a whole new listening experience for the consumer. And the customers are coming - SDARS looks poised for success in America.

2.0 Digital Radio Broadcasting & Delivery by Satellite in Australia

Studies on Digital Radio Broadcasting began in the mid-90’s in Australia, and like many other countries, the debate has continued to center around the transition from analog radio to digital radio, the choice of transmission standards, and receiver economics.

Since 1997, there have been a variety of tests conducted to test DRB technology in Sydney, Melbourne and Brisbane of which the DR 2000 consortium is a key player [8] [9]. Recently the Australian Broadcasting Authority (ABA) in December 2001 agreed to further trials in Sydney, where the Australian Broadcasting Company (ABC) have been testing; Eureka 147, Digital Radio Mondiale and IBOC terrestrial based systems [10]. Despite the studies and trials, a choice between the following systems is yet to be made;

- Eureka 147 - Terrestrial DAB using OFDM (orthogonal frequency division multiplex)
- In Band On Channel (IBOC) -a hybrid analog/digital system using existing transmitters.
- Worldspace (System D_h) - a hybrid satellite/terrestrial system
- Digital Radio Mondiale (DRM) - using high-efficient audio compression on AM transmitters
- Other technologies

Some of the main issues are the cost of changing vs. modifying transmission systems, use of VHF & L-band spectrum, receiver price points, and value proposition for the customer. The consensus is, that offering digital quality alone just won’t cut it;- what is needed is an attractive service as well. Both IBOC and DRM, while clever technically, are a compromise because they do not have sufficient capacity to offer any major new service. IBOC potential capacity is likely to be hindered for a long time by the requirement to simulcast both analog and digital signals.

While most of the focus is currently on terrestrial systems, the Australian Broadcasting Authority has continued to include the option of delivery by satellite by maintaining the ITU filing for DBSTAR satellite at 151.5E. longitude. In 1999, it refiled with modified beam patterns covering different parts of Australia. In 1996, in its report [11] the Digital Radio Broadcasting Task force concluded that "Satellite delivered DRB is the only technology that can economically deliver radio broadcasting to all parts of Australia, to fixed, portable and mobile receivers." It further pointed out that "there are advantages to having common receivers for both terrestrial and satellite transmissions'

In an update on system developments of DRB [12], Bob Greeney noted that Worldspace and XM Satellite Radio offer potential choices for Australia and that Worldspace was proposing a system in which hybrid terrestrial/satellite operations would be possible.

Building and launching new satellites and up-link facilities is expensive. A single DAB Satellite would be at least US $400m, while providing a mobile service would require an additional satellite for the path and time diversity, making the investment close to that of XM and Sirius radio - $1billion. For fixed and portable applications, Worldspace has been very successful not only in providing coverage from their three satellites Afristar, AsiaStar, Ameristar, to now almost all developing countries, but also in helping bring down receiver prices. In India, prices of receivers are now around $220 the same price as SDARS in the USA [13]. Worldspace's strategy is an excellent example of using the broadcast nature of satellites to rapidly provide global needs for information, education and entertainment albeit only on a partial commercial basis.

With its high initial investment, a new commercial satellite radio service based upon limited return on investment, with small numbers of subscribers can be hard to justify. In markets like Australia terrestrial digital broadcasting which allows lower initial investment and incremental investment is likely to prevail.

3.0 Globalstar SDARS - an Opportunity for Australia?

If satellites and receivers were available at a low cost, then, because of its nationwide coverage at low cost, broadcasters would seriously consider using this technology. Low cost satellite radio receivers are now a reality, but the satellites are still hundreds of millions of dollars. But, what if, there was a suitable satellite system available at a fraction of the cost?

The authors believe that while Australia has an orbital slot reserved for a geostationary digital audio broadcasting satellite, DBSTAR at 151.5 East, there may soon be an opportunity for a new, lower cost way of radio broadcasting by satellite.

What we have in mind is using the Globalstar constellation and adapting the technology developed for SDARS in the USA to form a Globalstar based-SDARS having 25 high-quality audio channels and providing complete coverage to all parts of Australia.

In figure 2, we compare the relative ratings of different broadcast methods, using capacity, cost, quality of service (QoS) and coverage.

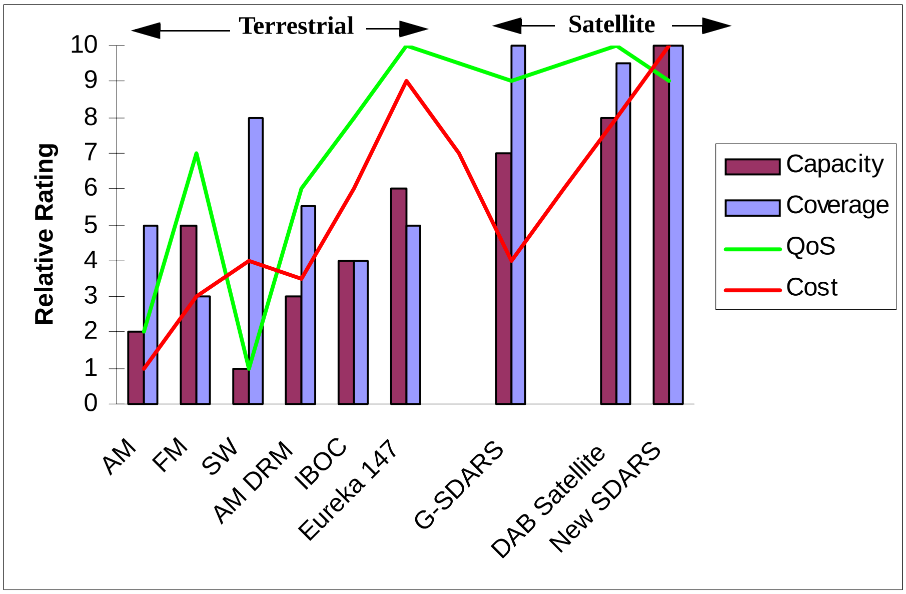

FIGURE 2. Relative Merits of Different Broadcast Schemes

From the terrestrial choices, Eureka 147 requires new equipment to be deployed and new frequency bands to be assigned - it has the promise of good capacity & reasonable range but the cost of serving everyone is huge, so it is likely to be used in cities and surrounding areas. This leaves people in the outback relying on the poor quality offered by shortwave, AM or a limited number of FM services. IBOC and DRM systems are clever ways to minimize transmitter upgrade costs and improve the quality, but ultimately they are limited in either capacity, coverage or both. Satellites solve the problem of coverage, capacity and quality of service simultaneously, but the cost is very high initially which presents a barrier to its use. On the other hand, Globalstar SDARS provides all the benefits, but potentially at the fraction of the cost. The ability or not, to use the constellation will be based on how Globalstar Limited Partnership is re-structured and the considerations of alternative applications such as this one. If the constellation is valued by the marketplace it is likely that it will be worth little more than Iridium (<$25M) or Orbcomm ($15m).

Despite the system's excellent quality & coverage, and the truly great engineering achievement in designing and building the system, the sad reality is that revenues from mobile satellite services are "capped" by a eroding price for the service, and the diminishing number of consumers that find themselves out of range of cellular telephone systems.

The growth of SDARS subscribers and associated revenues, available only recently, is strong evidence that SDARS can produce more revenue than mobile satellite services, as the following data indicates:

- XM Satellite added 136,500 subscribers in the first 9 months of operation in the USA alone, compared with Globalstar whose total subscribers grew to a mere 66,000 in three years, prior to bankruptcy.
- As of March 31, 2002, revenues for XM Satellite Radio stood at $1,785k compared with Globalstar at $3,870K - approximately 1/2.
- The SDARS adoption information does not include Sirius Satellite Radio.

With Satellite Radio now heard across North America (Sirius & XM), Africa, South America and Asia (Worldspace) and plans for European Satellite radio now under way, (Global Radio) and the Alcatel-Worldspace partnership for a European DAB system, a short window of opportunity exists now for Australia to utilize the Globalstar constellation for its own satellite radio system.

3.1 The Concept

Our concept is based upon comparing SDARS and Globalstar space segments RF power and bandwidth resources. It would have to be validated by detailed analysis, nevertheless the principle is fundamentally sound - section 4 explains it.

Even with a sound technical solution, the following agreements would also have to be reached:

1. Obtaining a timely agreement to lease capacity on the Globalstar constellation over Australia, which may include use of existing gateway antennas. If an SDARS-only service was used, then agreements with displaced MSS customers, to move to an equivalent service (e.g Iridium), would be needed.
2. Obtaining licensing agreements to use the SDARS technology, and contracts with manufacturers to develop and manufacture Broadcast equipment and radio receivers at an acceptable cost and in a timely manner.

Items 1 and 2 amount to new businesses for both Globalstar and its partners and SDARS service providers, and are outside the scope of this paper.

3.2 Technical Possibilities

There are two ways for Globalstar to carry SDARS.

1. Modify the Globalstar airlink and integrate it with SDARS components - a CDMA airlink with higher-level layers from SDARS.
2. Modify SDARS transmission scheme and the receivers, to use the Globalstar space-segement.

The easie & quicker one is to modify an SDARS transmission scheme and radios to suit the Globalstar space-segment, leaving the terrestrial part untouched. Since the Sirius transmission scheme is designed to work with simple repeaters like Globalstar, we have in mind modification of that transmission scheme, rather than XM which uses on-board multiplexing. We are not saying that a solution using the XM transmission scheme is not possible, but that it represents a more complex approach.

There are other options, which we don't discuss here:

- Could the existing mobile satellite service and SDARS co-exist on Globalstar?
- Could the L-band return link be used to make SDARS interactive (2-way SDARS)?
- What would be the number of channels achievable in a fixed and portable application instead of mobile? Similar to a Worldspace-type application.
- Would the Australian Broadcast Authority and Australian Communication Authority allow the re-use of the MSS bands for broadcasting in their country?
- How well could G-SDARS be integrated in to Australia's terrestrial strategy for digital radio broadcasting? Noting that SDARS terrestrial repeaters could be used to originate local programming content.
- Can a business be developed that simultaneously, satisfies the needs of broadcasters, customers, Globalstar, SDARS providers & equipment manufacturers, and all legal and regulatory interests?

Section 4 describes a concept of a one-way SDARS system, by considering the basic parameters of power and bandwidth at the physical layer and drawing some general conclusions based upon comparison of the Sirius and Globalstar space segments. We have not examined any of the high layers, nor been able to analyse the links in detail because this information is proprietary to the SDARS community.

3.3 Programming Options

In this proposal, Globalstar-SDARS would be just an alternative technology to deliver a service, but it is development of a new type of service, with diverse programming content, matched to the needs of Australians, that will be important. In America, the value proposition offered by XM and Sirius Satellite Radio is clear – American listeners are faced with lots of free AM/FM stations playing repetitive 50-track playlists, poor variety, interruptions from frequent commercials and lots of "DJ" talk, so listeners are motivated to pay for a better service. But in Australia, who will generate, manage and arrange this programing content? We summize a number of possibilities;

- Australian Broadcasters who wish to simulcast existing channels to a wider audience
- International broadcasters who may wish to broadcast existing programmes to Australia e.g. BBC World Service News.
- New radio stations which lease an SDARS channel.
- WorldSpace, XM Satellite Radio and Sirius Satellite Radio who may wish to offer some of their programmes.
- Streaming Internet radio

While the better sound quality will be a bonus, it is not the major reason for subscribing in the USA [14]. Australian and USA listeners probably share similar attitudes towards advertising, talk interruption and music tastes; however in the USA the majority of listeners are in the car, compared with Europe and Australia where people listen to the radio at home, outdoors and often at work. This implies that in Australia, focus should be on portable and fixed receivers or the hybrid home/car type, like the one on offer from SONY [15].

4.0 Merging Globalstar and SDARS Technology

Prior to the introduction of Iridium and Globalstar satellite telephones in the late 90s, there were few consumer products using satellite communications. Iridium, Globalstar and now SDARS has changed that, by offering. low-cost, consumer products to the masses. This has been an evolutionary step for the satellite communications industry.

Producing these products at prices that customers are willing to pay, drives the design of the transmission system. For example, to deliver an acceptable signal, free of dropouts, to moving vehicles, though a wide range of propagation conditions means that some of path diversity is needed. Signal interruptions, due to blockage, have to be avoided by using additional satellites/ terrestrial repeaters or both, which makes mobile systems very expensive compared with fixed receivers. Globalstar and SDARS systems share this capability and thus the technologies are similar.

The difference between MSS and SDARS, is that the Globalstar telephone service is tolerant to interruptions of service. Firstly, interruption depends upon the likelihood that the user will try to make a call, or continue a call when all paths to satellites are blocked - this is a low probability. Secondly, if the call is lost the user will re-dial.

On the other hand, the probability that SDARS listener will experience program interruptions due to blockage on both paths, for example when travelling under a bridge, is almost guaranteed, because the service is on all the time. To solve this outage problem SDARS designers added two more features - time diversity and terrestrial repeaters. In G-SDARS this would also have to be used, but it could be omitted if G-SDARS was a fixed and portable application like the Worldspace system.

Globalstar & SDARS are both mobile satellite systems, so they are an obvious technology combination. Table 1 shows that the RF parameters of the Globalstar repeater compared with Sirius are close enough that adoption looks immediately feasible. We show XM parameters for comparison, but as mentioned earlier, we are not sure if this transmission scheme could be adapted, due to the on-board RF multiplexing scheme.

Parameter	XM Satellite	Sirius Satellite [16]	Globalstar
Peak Satellite EIRP Polarization	66dBW Circular	67dBW Circular	31dBW LHCP
EIRP variation/beam/ path	two 66dBW spots in NE/ NW CONUS with min. 60dBW across service area	no coverage details avail- ble. Assumed to be flat CONUS beam, 3dB down at EOC	1-3dB beam ripple isoflux corrected for path variation
Bandwidth allocated	12.5 MHz (SDARS - USA)		16.5MHz (Global MSS)
Payload type	Mux/Demux	Repeater	16 channel repeater
Frequency Bands	2332.5-2345.0 MHz	2320-2332.5 MHz	2483.5-2500 MHz
Carrier occupied band- width	3.8MHz	4.2MHz	1 MHz (proposed)
Orbit parameters	Geostationary	HEO -geosynchronous inclination 63.4 deg Arg of perigee 270 deg RAAN 45,165,285 Apogee Longitude 96.0W Eccentricity 0.2684	Low earth orbit plane inclination 52 degrees
Coverage	CONUS		Global – custom
Satellite altitude	35,800kms	47,102kms Apogee 24469km Perigee	1,414kms at zenith
Saturated Power flux density at earth	-97 – 103dBW/M2	-97.5-100.5dBW/M2	-103 - 107dBW/M2
Delta PFD	0 to +7dB	+6.5	NA
Difference in band cen- ters	-153MHz (-6.1%)	-165MHz (-6.6%)	NA
Doppler Shift (max) Doppler Rate (max)	<+/-100Hz	+/-4.8KHz 21Hz/min.	46.5KHz 12.4KHz/min.

TABLE 1. Comparison of Globalstar and SDARS Satellites

Considering Globalstar and Sirius satellites, we see the following differences;

The power flux density that Globalstar can produce is about 6dB less than Sirius.

To compensate for the reduction in power flux density, we propose reducing the aggregate symbol rate (increasing E_s) of the SDARS time division multiplex (TDM) from around 4Msym/sec to 1Msym/sec - a factor of times 4 or 6dB. The corresponding carrier bandwidth would then be 1MHz. On the face of it, this would result in reduction in the number of channels from 100 to about 25.

The frequency bands are within 7% of each other.

Re-tuning the SDARS antennas by this amount, to the MSS frequency band is feasible, including leaving the terrestrial repeater frequencies unchanged.

Globalstar has 16.5MHz vs. 12.5MHz for SDARS

One might be tempted to exchange bandwidth for power in the Shannon sense, to restore capacity. But as we shall show, all of the 16.5 MHz of bandwidth is used to overcome a limitation in the Globalstar S-band antenna.

The Doppler shift and its rate of change is higher on Globalstar

Re-designing the SDARS demodulators to track higher Doppler rates is possible.

However, transmission engineers will be quick to point out that the following factors affect link performance;

- Propagation losses which depend upon the elevation angle and polarization effects
- Path diversity
- Frequency diversity
- Time diversity
- Doppler and its rate of change GEO/HEO vs LEO

Also the TDM signals contain overhead channels which may not be scalable. In the absence of detailed information regarding the SDARS transmission scheme and receiver designs we cannot estimate accurately the channel capacity, nor the Quality of Service. Also, when we make a direct comparison of power margins we may not be aware that SDARS airlink may be capable of providing more channels than are currently offered, through the use of techniques such as; statistical multiplexing, audio pre-processing, error concealment, diversity combining and newer audio codecs, with lower bit rates. Thus, the 100 channel limit benchmark assumed here may actually be higher.

4.1 Propagation Margins & Path Diversity

Power margin has to be added to the link budgets to account for multipath propagation and times when the path between the receiver and satellite gets shadowed by things like trees.

Path diversity is added to solve the problem, when one path is completely blocked. Both XM, Sirius and Globalstar use different path-diversity strategies, which result also in different propagation margins that are needed to overcome fading. Predicting which one is the best in practice is not straightforward as it may seem, because it depends on the position of the user relative to their environment, and the position of the constellation at any point in time. In the next section we briefly review the strategies of each system, to see how Globalstar path diversity compares, it is not an analytical approach, but is intended to give the non-expert reader the idea of path diversity. The experienced reader is directed to reference [17] for detail.

4.1.1 Sirius Satellite Approach

Sirius Satellite approach is to keep the elevation angle to the satellite high - between 60 and 90 degrees inside the service area. They achieve this by using a highly elliptical orbit [7]. Figure 3 shows the elevation angle to Sirius satellites from Bangor, Maine in the north east extreme of America. Similar elevation angles occur at other places. Using high elevation angles, simultaneously minimizes both the propagation loss and the likelihood that a path will be blocked. Orbits similar to these have suited the Russians for many years, as much of their country is at high latitudes making communication via the geostationary troublesome. In the mobile application, high elevation angles avoids interruptions due to high-sided vehicles, high rise buildings and shadowing on tree-lined roads. Sirius satellites are in a highly elliptical orbit which also remains stable and geosynchronous, thus avoiding daily spacecraft manoeuvres. Satellites in these orbits appear to “hang” over the service area for 16 hours at a time. See the birds-eye views in figure 4 and imagine how the satellite can see down in between high rise buildings in cities. Satellites in these orbits spend a longer distance from the earth than a geostationary satellite, resulting in about 1.5dB more fee-space loss, but this is more than offset by the lower propagation margin need ate 60 degrees compared with 30 for example.

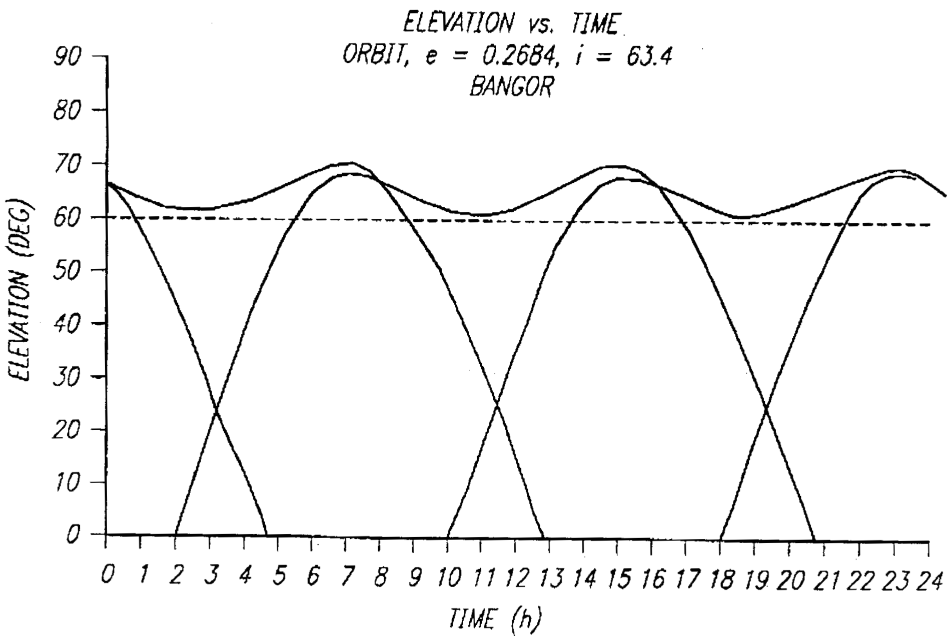

FIGURE 3. Example Elevation angles to the Satellites in a HEO Orbit from Bangor Maine [7]

Since the satellites are moving, there is a signal handoff from one satellite to the next as the setting satellite leaves the service area (S1) and a new one enters (S3). The three satellite are in the same orbit but spaced apart by 8 hours, thus three handoffs occur per day. The handoff is masked by the time diversity function in the receiver.

FIGURE 4. Birds-eye view from each Sirius Satellite - Courtesy of [18]

Because the elevation angles are 60-90 degrees the azimuth/elevation volume appears as a cone above the user. Not all of this cone is available to all users in the service area. On the coasts, satellites are never seen to the west on the west coast, and vice-versa on the east coast. In the center, satellites appear to circle in the sky, providing diversity in azimuth of up to 360 degrees. Azimuth diversity helps when there is continuous blockage in one direction - for example when a vehicle is driving past lines of trees, buildings etc. However, in Sirius case the high elevation angle allows the satellite to see over the top of high obstacles.

4.1.2 XM Satellite Radio

XM Satellite Radio uses two satellites in geostationary orbit located at 115W and 85W to provide path diversity, but because these satellites are always seen to the south of the service area, the range of azimuth diversity is limited to approximately one third of the hemispherical AZ/EL coverage volume. The average elevation and the range throughout the service area are also lower that in the Sirius design. Table 2 shows pointing angles from sample locations lying on the edge of the service area.

TABLE 2. Elevation/ Azimuth Angles to Rock and Roll Satellites in degrees

Location	85W	115W
Bangor, ME	35.1 / 202.2	21.4 / 236
Miami, FL	59.4 / 190	41.2 /237
El Paso, TX	46.3 / 143	51.1 /195
San Diego, CA	38.4 /130	51/175
Seattle, WA	24.7/134.4	34.9/170

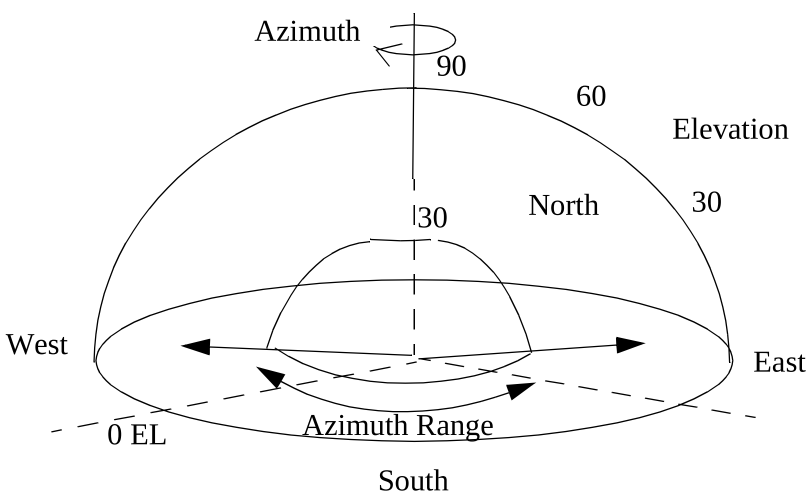

FIGURE 5. Geostationary Satellites have a limited visibility of the hemispheric coverage volume

In figure 5, you can visualize only a small volume of the hemisphere being available to the south. The limited azimuth and elevation range means that a larger number of fill-only terrestrial repeaters is required, plus at lower elevation angles more power is needed. XM compensate for this by radiating 6dB more eirp at high latitudes. Figure 6 show EIRP levels generated by the Rock and Roll Satellites and the birds-eye views from the satellites.

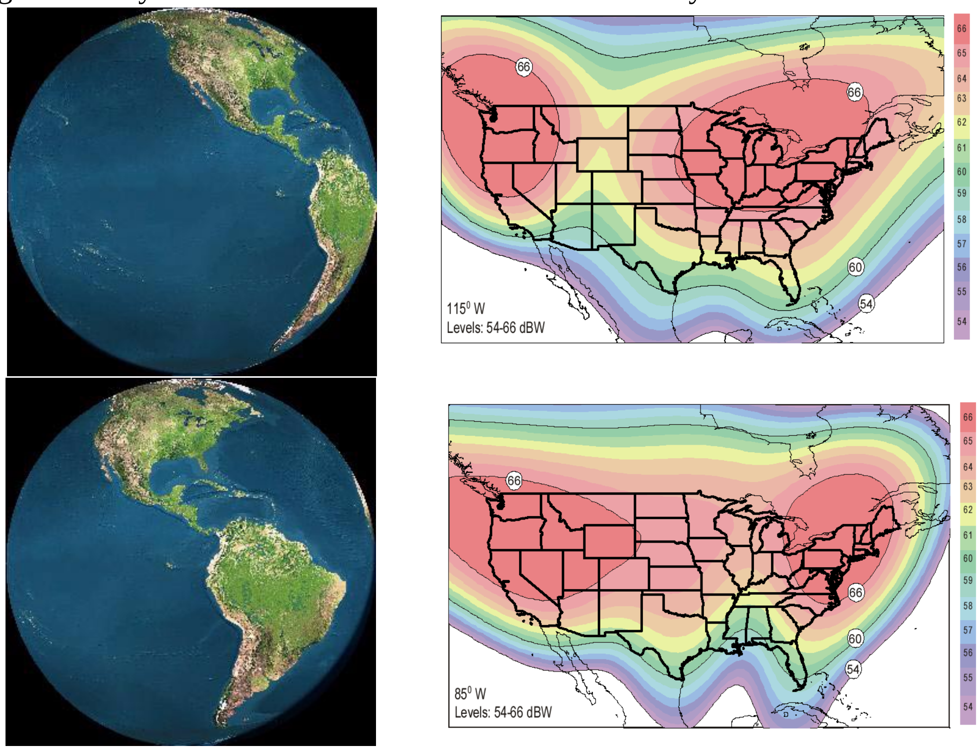

FIGURE 6. Birds-eye views [Courtesy of [18] of Rock and Roll and corresponding EIRP.

4.1.3 Globalstar

In Globalstar, path diversity is provided by multiple satellites, which appear at changing elevation and azimuth angles through the hemispherical volume of the sky. However, since the orbits are not synchronized to the earth, the number of satellites and their location, with respect to the observer, is not fixed (like XM Satellite) or periodic (like

Sirus). Instead the umber of satellites that are visible is based upon a probability, which also depends on latitude. See figure 7

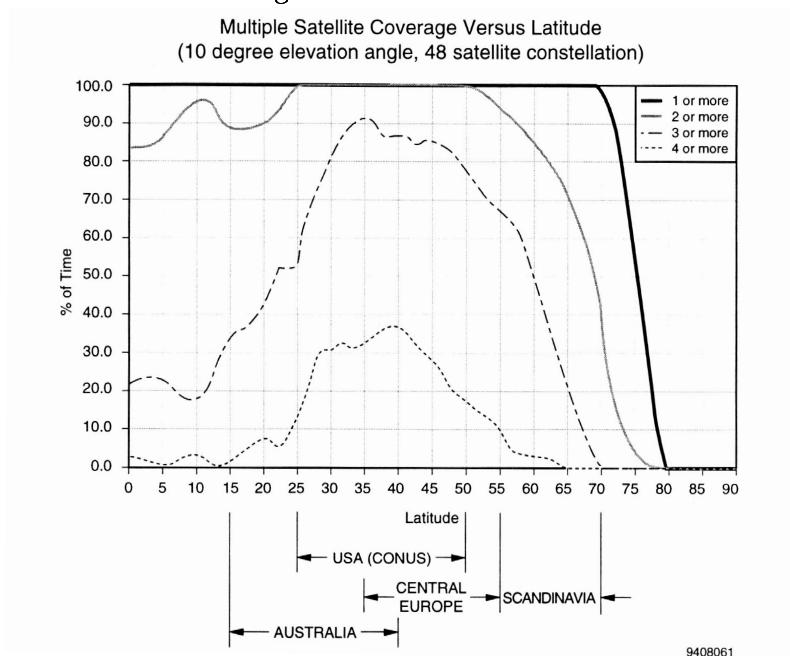

FIGURE 7. Visibility of Satellites vs. Latitude

Similarly the elevation angles follow a probability distribution that also depends upon latitude, the median value being around 25 degrees [19]. In azimuth directions, satellites often appear at wide separations, which greatly reduces the probability that two or more paths will be blocked at the same time. This helps because the mean elevation angle to Globalstar satellites are lower than Sirius, and need higher fade margins. However, there will be 2 all the time, often 3 and sometimes four satellites that can provide diversity, thus reducing the probability of blockage to exceptionally low levels. Figure 8 shows a snapshot of the constellation over Australia.

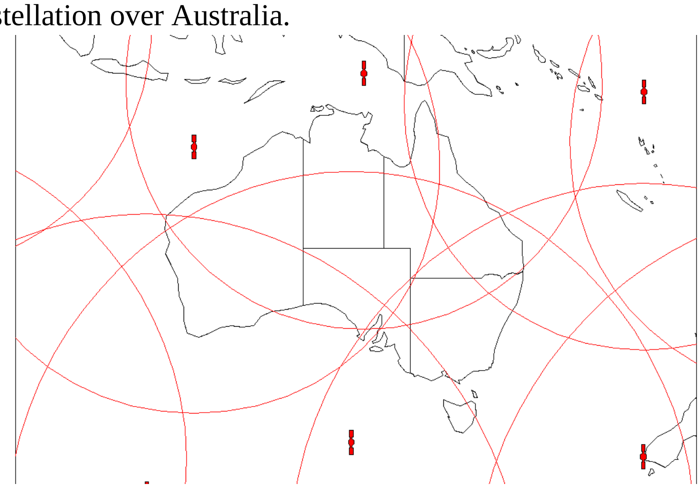

FIGURE 8. Example Satellite Coverage over Australia - 10 degree field of view.

In the revised SDARS receiver it may also be possible to obtain more diversity gain by combining 3 or 4 satellites signals instead of two, helping to offset the propagation loss difference.

In Figure 7, Australia lies at a latitude from 15-40 degrees, but between 25-40 degrees latitudes, where most of the population live, two satellites are always available 100% of the time, and a third one for up to 80% of the time. In the Northern part of Australia, there is a significant amount of time, up to 10% , where only one satellite is available. For SDARS, in a mobile situation, this quality of service may suffer. However, it is feasible to cover these sparsely populated, but vast areas, by using high power SDARS repeater located on mountains, to restore the availability.

4.2 Frequency Diversity.

Both SDARS systems use frequency and time diversity by radiating a duplicate carrier from the other satellite which is shifted in frequency (approx 8 MHz) and time (4 secs). The difference in frequency between the two paths helps to combat frequency selective fading caused by multipath propagation. Frequency diversity is effective only when the frequency separation is greater than the coherence bandwidth, $B_{Cb} = 1/2T_m$ where T_m is the multipath spread. The differences in the Globalstar case are; a 7% difference in frequency, a higher rate of change of Doppler. The difference in frequency between carriers will be 1 to 15 MHz (see later), and the ability to use many more than 2 carriers for combining. Further study is required to see what the frequency diversity gains maybe.

4.3 Time Diversity.

Time diversity is used in both systems. The TDM signals on each satellite are offset in time with respect to each other, so that in the event of a temporary blockage to both satellites, (driving under a bridge for example), the receiver can use the early and late data streams which are stored in a 4 second buffer, to reconstruct a continuous signal, thus avoiding dropouts. Figure 9 illustrates that all time slots are available by offsetting the two streams.

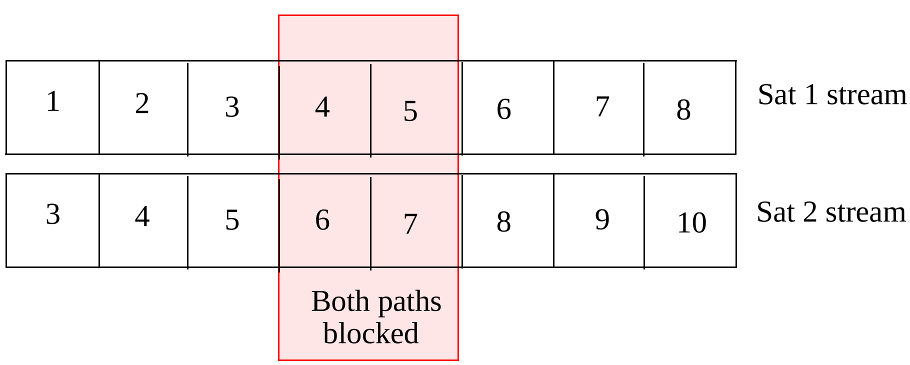

FIGURE 9. Principle of Time diversity

We believe that this system can be re-used with Globalstar, by ensuring that the delayed TDM carrier is always assigned to an adjacent satellite. In principle, this technique could be extended to use two time offsets for three satellite.

4.4 Doppler and its Rate of Change

Due to its lower orbit, Globalstar has much larger Doppler shift and rate of change compared with the Sirius system. Thus, the receiver designs would need to be modified to acquire and track the satellites in time and frequency. In Globalstar, the gateway knows the orbits of the satellites and dynamically pre-corrects for the uplink Doppler shift and its rate of change during each satellite pass, leaving only the Doppler effects on the space-earth S-band path.

5.0 Using the Globalstar Space Segment

Globalstar is a constellation of 48 low earth orbiting satellites, which are arranged in six orbital planes in which 8 satellites are equally spaced per plane. Each plane is inclined at 56 degrees to the equator. The orbits are circular, have an altitude of 1414km and a period of 114mins. This results in global coverage up to +/-70 degree in latitude for all longitudes - see figure 10.

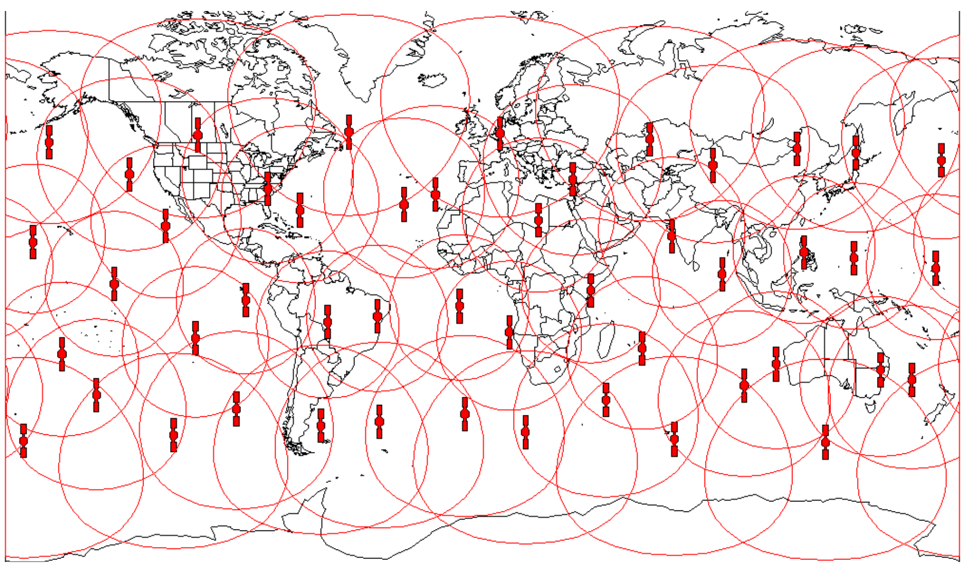

FIGURE 10. Snapshot of Globalstar Constellation

Service areas are defined in a completely different way to satellites in geostationary or highly elliptical orbits. Rather than having a single beam that illuminates the service area from one satellite, each LEO satellite is used for just a short period of time as it passes over the desired service area - all satellites in the constellation visit the service area approximately every two days. Beams from available satellites are illuminated dynamically in a optimum sequence, so that there is always coverage over the service area. Thus, any service area can be defined within the global limits of constellation coverage, by simply choosing the gateway location. In the geostationary case you choose the orbit location. The beam power is essentially constant because the antenna compensate for the varying range by using an isoflux corrected antenna. The gateway operations control centre (GOCC) controls which antenna will use which satellite, which beam will use which frequency, and in what sequence this will happen based upon a service area that has been pre-defined. There are 4 antennas at a gateway site.

5.1 Globalstar Communications Repeater

At the satellite level, each satellite comprises two frequency translating repeaters. Signals from the gateway are uplinked at 5GHz via a horn antenna to a bank of 16 C-S repeaters, which feed each beam of a sixteen beam phased array antenna - figure 11. Each C-S repeater is tuned to a particular C-band feeder link frequency. Each repeater has a programmable SAW filter and 18dB attenuator to control radiated noise, and has a bandwidth of 16.5MHz. For the SDAR application these settings would be optimized and then fixed.

Signals from satellite phones are received at the satellite at L-band via a multi-beam phased array and are downlinked via the 7GHz horn to the gateway. The L-band portion of the payload would not be used in the solution described here), and thus is not discussed further.

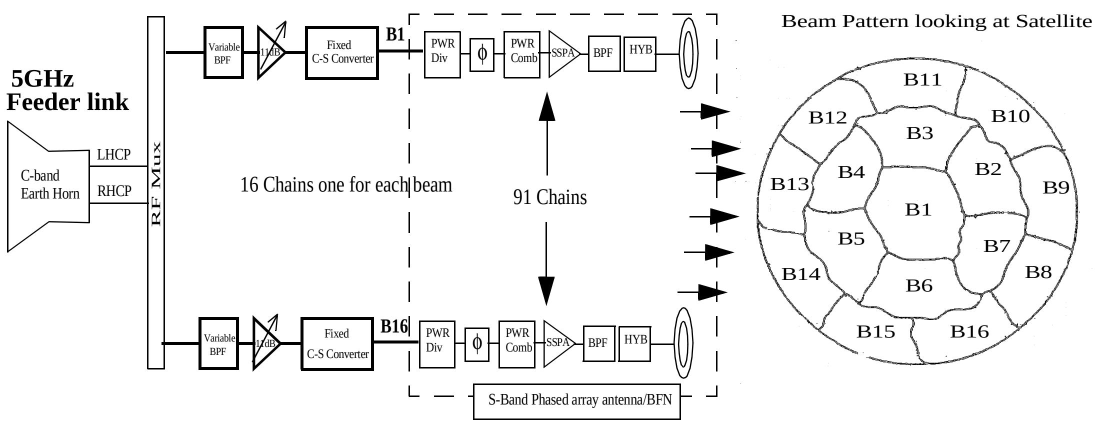

FIGURE 11. Satellite Repeater and S-Band must-beam antenna

Returning to the S-band antenna, it comprises 91 SSPA modules that are driven by a programmable DC voltage of 3 - 8.4 Volts. When operated at 8 volts, each beam, B1..B16 produces 31dBW. Beams are "lit up" sequentially, under the control of the gateway as the satellite flies over the desired service area, by accessing the desired beam by choice of uplink frequency. Its rare that all beams are used at once; beams can stay on as long as 20 min. but typically it is much less than this.

The phased array antenna was designed for a CDMA airlink which is designed to tolerate large amounts of co-channel interference, thus isolation between beams is not very high. The middle beam, B1, is surrounded by neighbouring beams B2.B7 whose sidelobes leak in to beam 1, reducing the C/I to around 4dB. The outer to inner beam isolation while better still, can only achieve C/I of around 10dB. Thus, the same carrier frequency cannot be used for each beam. However, if the Sirius TDM carrier rate is reduced by a factor of 4, then the occupied bandwidth would be approx 1MHz, and because there is 16.5MHz bandwidth per beam, it is possible use 16 different carrier frequencies one for each active beam, to avoid the poor beam isolation. Table 3 shows a new channel plan including feeder link frequency.

TDM CH#	Beam number	S-Band	Feeder link & polarization	
1	B12	2483.7000	5113.26	LHCP
2	B9	2484.7500	5112.21	RHCP
3	B14	2485.8000	5130.54	LHCP
4	B11	2486.8500	5129.49	RHCP
5	B16	2487.9000	5147.82	LHCP
6	B13	2488.9500	5146.77	RHCP
7	B10	2490.0000	5165.11	LHCP
8	B15	2491.0500	5164.06	RHCP
9	B1	2492.1000	5182.38	LHCP
10	B8	2493.1500	5181.33	RHCP
11	B6	2494.2000	5199.66	LHCP
12	B3	2495.2500	5198.61	RHCP
13	B4	2496.3000	5216.94	LHCP
14	B7	2497.3500	5215.89	RHCP
15	B2	2498.4000	5234.22	LHCP
16	B5	2499.4500	5233.17	RHCP

TABLE 3. New TDM Carrier Frequency channels

In the gateway, the gateway controller will need to be modified to add a new SDARS channel processor. The modified gateway controller will then control not only which beams to light up and when, but also the assignment of SDARS carriers to beams. This controller will have the following functions;

- Dynamic assignment of gateway antenna to satellites
- Assignment of feeder link frequencies to active beams over the service area
- Dynamic assignment of SDARS TDM channel number to beams, to avoid interference

Sometimes there will be more than 16 beams in use, so interference is possible if carrier frequencies are used in adjacent beams. In figure 12 we show two overlapping beams one from each satellite. The SDAR channel processor thus has to minimize the probability that two frequencies are used on overlapping beams -this is an example of poor assignment.

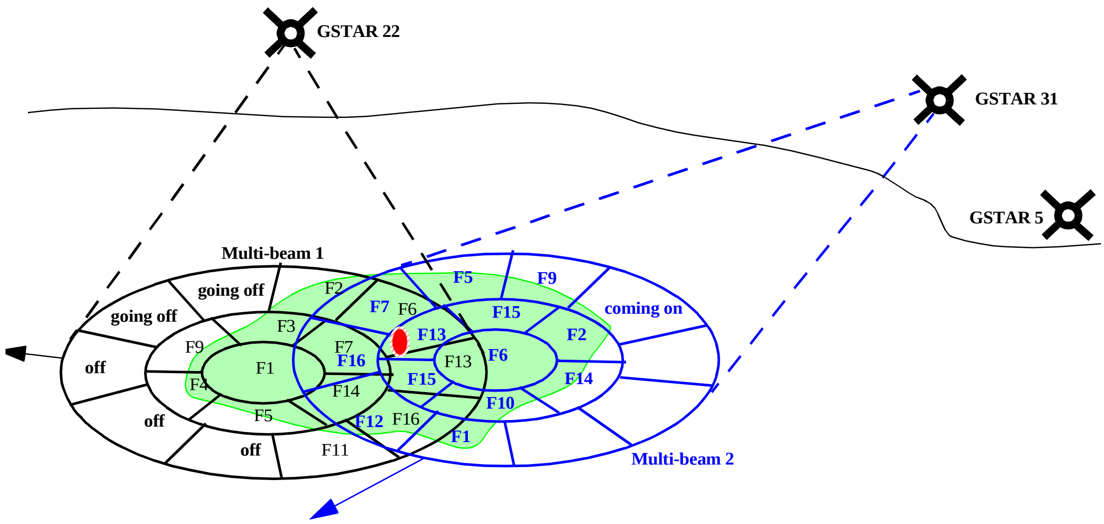

FIGURE 12. Example of faulty assignment of TDM channel frequency

In cases where carrier frequencies are re-used, they must be separated over a wide geographical distance to obtain the best isolation possible. However because the beam isolation is low and the user antenna has omni-directional gain, the receiver will actually see all of the carrier frequencies in use on all satellites in view, but at different levels. Figure 13 shows the case of the poor assignment shown above. Not all frequencies have been used and the geographic separation principle has not been applied.

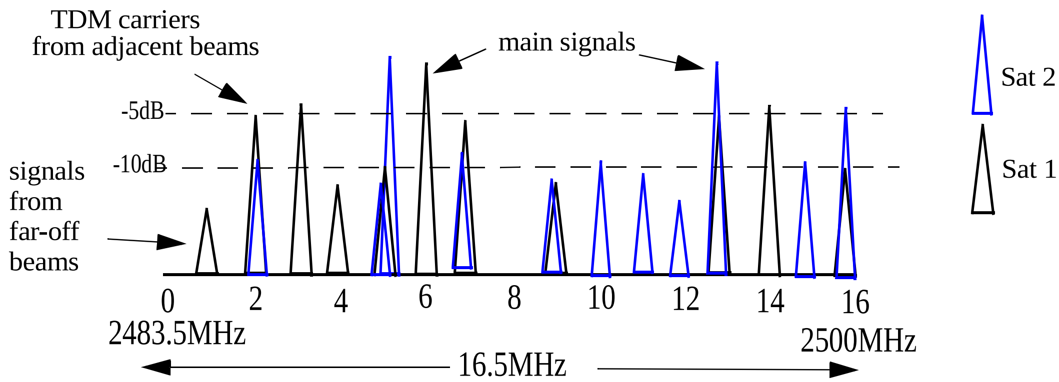

FIGURE 13. An omni-directional antenna sees a number of TDM carriers at different frequencies.

As a result, out of the highest power carriers, 5 and 13 suffer a C/I of around 10dB, but carrier 6 is clean. In fact, the channel processor should have picked channel 8. Nevertheless, F3 and F14 were also available, but at a lower power and might be useable in some form of combiner in the receiver. The purpose of this example is to show that using 16 different carriers results in a lot of redundancy, and with careful design of the assignment algorithm, the interference scenario shown in figure 12 will be minimized.

5.2 A new SDARS Receiver

To use the proposed Globalstar 16 carrier plan, the SDARS receiver would have to be modified. Instead of having a two receiver arms on two separate carrier frequencies, now it needs 16. This is by far the most involved modification. A notional receiver front end design is shown in figure 14

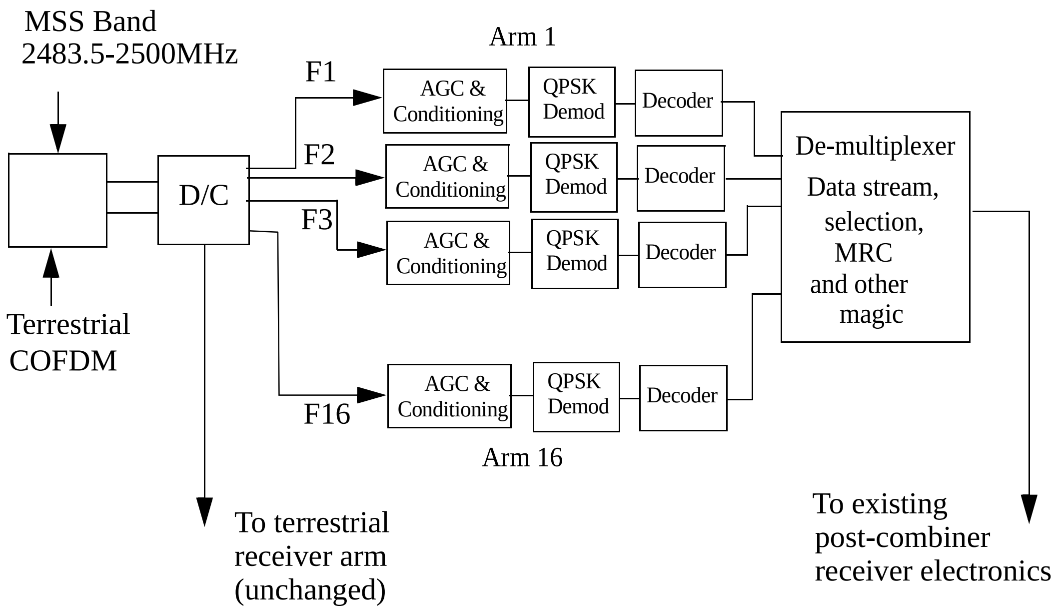

FIGURE 14. Notional Design of G-SDARS Multi-channel Receiver Front end

The following changes would be needed;

- Re-tuning the Satellite front end - the antenna, LNA, mixer and filters to the MSS band.
- Modify the receiver arm for the narrower bandwidth, lower symbol rate, higher Doppler shift/rate of change.
- Develop and implement a strategy for combination of up to 16 signals using switching and or soft combining methods.

Whether our concept is feasible depends upon the possibility of developing such a receiver in a timely and cost effective manner. The number of the channels that we have estimated also depends upon what diversity gains may, or may not be, possible from this type of receiver.

6.0 First Generation Satellite Replacement

The 48 satellite Globalstar system has very few inherent wear-out mechanisms. Reaction control systems, fuel supply, batteries, solar arrays and momentum wheels are the key components that limit spacecraft lifetime. Based on a recent review of these system components by SS/Loral, the spacecraft manufacturer, it is anticipated, with quite high probability, that the spacecraft should last for at least 12 years in orbit. The oldest spacecraft in the constellation are currently 4.5 years old. It is particularly worthy to note that all spacecraft have an abundant station keeping fuel reserve available, which allows each to complete its mission and to then to allow ground controllers to remove the satellites from the operational orbit to a higher “graveyard” orbit.

Seven to eight years from now, it will be necessary to begin to launch replacement satellites. If the constellation design remains the same, then a minimum of 48 replacement satellites must be launched. A key issue arises with respect to the entire notion of using a constellation of LEO satellites vs. a few GEO spacecraft to serve the SDARS market. This is made a more complex decision, because constellations have their clear advantage when they are serving a global market. The proposed utilization of Globalstar, suggested in this paper, is for the provision of an Australian service. Furthermore, the economics of constructing a constellation are different than for a pair of geostationary spacecraft. The ratio of non-recurring engineering (NRE) to recurring engineering (RE) for the two system approaches, is actually quite different. In order to determine the business impact of replacing the constellation on the SDARS venture, we make the following assumptions.

We assume the current Globalstar system will be used by a number of semi-independent businesses on a global basis. One of these would be SDARS in Australia. We further estimate that the SDARS business in Australia would contribute up to 1/3 of the replacement cost of the satellites, including the NRE plus RE components of the second generation satellite system. This fraction would depend upon the type of applications that may have evolved, and whether other users could use new designs tailored for SDARS.

We assume the second generation SDARS satellite will use a simpler transponder payload which would reduce both the non-recurring development and recurring expenses. For SDARS the multi-spot beam system will no longer be required, so it will be possible, to use more efficient RF power generation equipment on-board, and to increase the capacity by about a factor of two. A change in transponder frequency may also be needed for regulatory reasons, to the Broadcasting Satellite Services band (or SDARS band). This would cause capacity to be split between the MSS and the new frequency band. Only a fraction of either band would be used for this system, leaving spectrum for traditional mobile satellite services and other expansion services.

Industry estimates place the current Globalstar satellite cost at approximately $25M USD per satellite, but we believe the second generation system would be much simpler and less costly with a target RE price of $15M USD per satellite. Further, we the development of the 2nd generation satellite could be accomplished for $200M USD.

This would bring the target price for a second generation replacement, for global use, to $1040M USD for 56 spacecraft (48 operational + 8 spares) and $315M USD for low-cost Soyuz-like launch vehicles. $100M USD would be needed for launch insurance. Applying the worse case, the SDARS business in Australia would pay up to 1/3 of this cost - $485M. This capital investment would be distributed unequally over 6 years (two years for development and 4 years for launch and satellite commissioning).

The $485M contribution is nearly equal to the price for two, HEO-type repeater satellites and on a cost vs. capacity basis a HEO or geostationary satellite might be a better choice. This suggests a trade study should be done to determine which type of system GEO, HEO or LEO would be the most cost effective.

6.1 Second Generation Satellite System Configuration

One of the “lessons learned” from experiences with LEO constellation satellite technology in the United States (Iridium and Globalstar being the two prime examples) is, in the absence of a sustained market for this type of spacecraft, the spacecraft cannot be replaced, even incrementally, without additional NRE expenditure. The problem is, if the satellite manufacturing line is shut down at the completion of a project, and there are no sustaining orders for further spacecraft, tooling is lost and components become obsolete. Both Iridium and Globalstar used highly specialized satellite components (e.g. S-Band power amplifier and antenna modules) which cannot be replaced in the future, without significant investment. This means that when the satellites are replaced, after many years of down time by the satellite manufacturer, the cost will be high. It is estimated that much of this cost, however, is associated with the payload portion of the system, which for Iridium and Globalstar were highly specialized.

It is proposed here, that one way to minimize the cost of the replacement process, if a LEO constellation continues to be used, would be to employ the current Globalstar bus concept, upgraded where needed, to replace obsolete technologies *and* to develop a new (simplified, high efficiency) transponder system.

The current Globalstar bus has proven to be a very reliable and quite straightforward. The bus uses redundant components in each subsystem, although not always in a 2:1 configuration. As currently designed, the attitude control system (ACS) is particularly robust and uses a Kalman filter system and redundant sun and Earth sensors. The geometry and configuration is such that, even after the loss of true redundant components, the ACS can operate in a still-acceptable “fail soft” mode in which the ACS, because of the Kalman filter can continue to operate but, with reduced attitude accuracy. On the other hand the spacecraft computer system (On-Board Processor Electronics or OPBE) uses a very old MIL-STD-1750A architecture that will certainly be in need of change by the time the current system is replaced. Software porting from the old to the new processor will certainly become an important issue.

Most important to our example here, the power subsystem delivers approximately 1650 watts of solar array power to the spacecraft at the beginning-of-life (and at autumnal equinox) and 1100 watts of power at end-of-life (EOL). 18% efficient GaAs solar cells are used to achieve this power production capability. The FORWARD link transponder system will deliver 320 peak watts of S-Band downlink power distributed between 16 beams. Beams EIRP is varied by ground control depending on the region of the Earth being served, however the average EIRP in each beam is nearly constant with an average value of approximately 30.5 dBW. The FORWARD transponder has an overall DC/RF efficiency of slightly less than 25% so that the peak DC power to the FORWARD transponder is 1440 watts. Given orbit eclipse conditions, array degradation over lifetime, and power consumed by the satellite bus itself, this power level cannot be sustained on an orbit average basis. During a time when the spacecraft is delivering 320 watts of S-Band RF power (peak conditions) the satellite bus must dissipate 1120 watts. The satellite system takes advantage of the times it is “over-ocean” (when there is virtually no traffic load) to recharge the spacecraft battery and cool off.

Let us now assume that the same bus approach (updated technologically as required) is used for the second generation system and employs approximately the same orbit altitude and inclination. We also assume that during the transit of any of these spacecraft over Australia, the satellite transponder payload will consume 1440 watts of power but, under those conditions it will dissipate approximately 720 watts of waste heat. Further, the spacecraft will also be capable of generating 1650 watts of power from the arrays at BOL and 1100 watts at EOL. The new spacecraft will have two FORWARD link transponders, one operating with a 1 MHz passband operating in the downlink frequency band 2483.5 to 2500 MHz and a second operating in possibly the BSS or SDARS band - 2310 to 2360 MHz and with a similar passband bandwidth. Each transponder will have a maximum power output of 300 watts (at the –1 dB compression point) and the HPA will be required to operate with an efficiency of 50%. This FORWARD link transponder system then, will consume 1200 watts and will dissipate 600 watts. This leaves an additional 240 watts of power for the RETURN link transponder and an allowable dissipation of 120 watts for that same transponder. Each of these transponders will then make use of a single isoflux (or ranging compensating) antenna, having a peak gain of approximately 12 dBi toward the spacecraft horizon (in a cone approximately 60× half angle from the NADIR axis of the spacecraft). The gain of the antenna in the NADIR direction is near 0 dBi, and the average gain over the coverage area is 6 to 7 dBi. This would allow each of the two transponders to produce between 30.5 and 31.5 dBW of EIRP. This EIRP is approximately twice that of the current Globalstar system but is split into two 1 MHz wide channels, each delivering approximately 25 channels of programming, time division multiplexed.

6.2 Adding a New Band

In order to implement a slightly more ambitious Sirius frequency plan as discussed in Section 6, three of the Globalstar spacecraft in mutual view of subscribers, would transmit the same 1.1 MHz wide spectral band but, offset by 5.2 MHz from one another - figure 15.

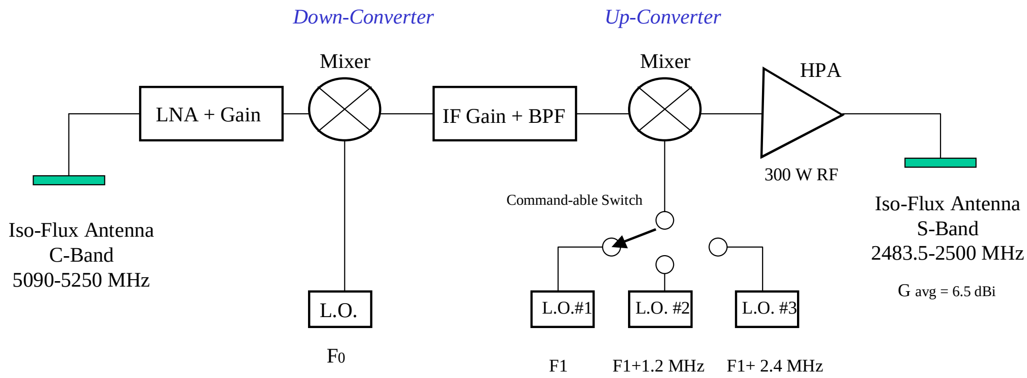

FIGURE 15. Second Generation SDARS Transponder for LEO

The signal ensemble for one of the two spacecraft would also be delayed in time by 4 seconds. This scheme improves multipath performance and allows the first-transmitted signal to be recorded and used IF the second signal experiences dropouts. So the total spectrum required to implement the hybrid scheme is 10.8 MHz, although each spacecraft is only actively transponding 4.4 MHz. The total spectrum available in the Globalstar FORWARD downlink is 16.5 MHz (2483.5 MHz to 2500.0 MHz). In order for the Globalstar system to be used as a broadcast system, the same 1 MHz TDM signal structure must be repeated on each satellite in each beam. In the C-Band feeder link this requires that 16 copies of the signal structure be transmitted on 8 frequencies and in two polarizations. One such scheme is shown in table 3 earlier.

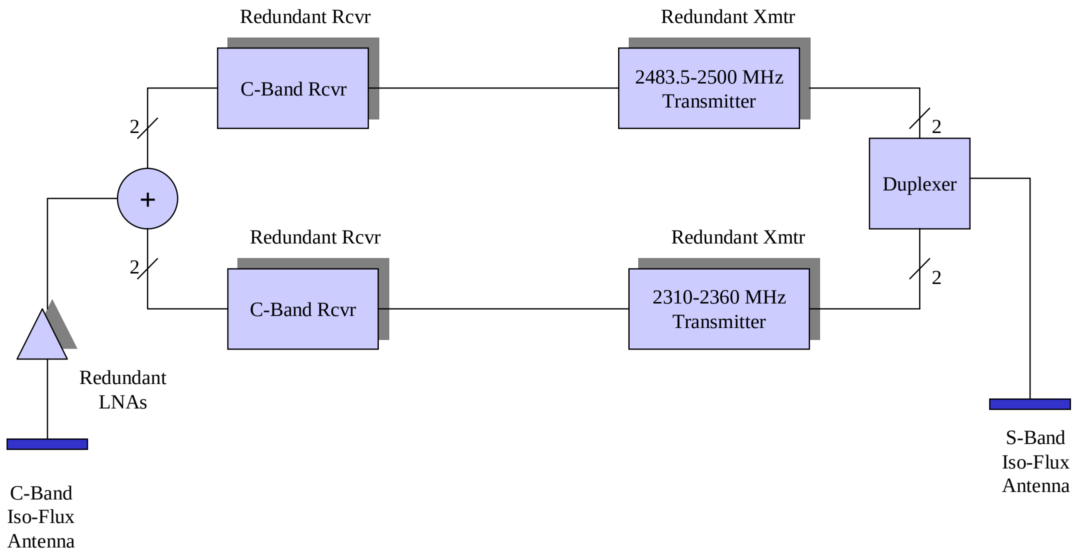

FIGURE 16. Simplified MSS/SDARS repeater.

The second generation system can be simplified considerably. Only a single 4.4 MHz signal is required to be transmitted on the C-Band uplink. Depending on whether the spacecraft is to provide the advanced or delayed version of the TDM signal structure the signal is mixed to one of two downlink channels spaced 6.4 MHz apart. The transponder becomes a simple frequency translator with one of two mixing schemes enabled during a given pass of the spacecraft over Australia. A simplified block diagram of the transponder is shown in figure 16

In order to implement a second transponder transmitting in the 2310 MHz -to-2360 MHz band, the same transponder could be “copied,” however, the new uplinked TDM signal would be moved several MHz away from the first uplink carrier in the C-Band feeder link spectrum and a different translation scheme would be used. Various redundancy schemes could be applied either at the component level or at the sub-component level. Here it is assumed that the transponder is implemented as two components (a receiver and a transmitter) with an interface at some IF frequency. These units are then duplicated four times (twice for redundancy at each frequency band).

7.0 Example Business Model - Kangaroo Satellite Radio

We use the example of a fictitious company, Kangaroo Satellite Radio to illustrate what revenue streams can be generated, and what operating expenses are incurred. Its worth noting that Kangaroo Satellite Radio (KSR) does not follow the same structure as XM Satellite or Sirius Satellite Radio. In fact, it is not a Broadcaster, but a kind of a satellite radio teleport.

7.1 Service Analysis

When both Sirius and XM satellite radio developed their service for US markets, they concentrated on offering the consumer a new listening experience. Well thought-out compilations of music, by category and type, a wide variety of national/international news, specialist talk and, to many, the pleasure of entertainment uninterrupted by advertising was the goal, with the promise of geographical reach coming second. In Australia, we speculate that the desire for some Broadcasters to re-broadcast programmes to all parts of Australia at a low cost is an attractive proposition in itself, but for the consumer, receiving distant stations alone, is unlikely to be a strong enough reason to subscribe to the service.

What will be needed is a new type of service tailored for Australian tastes, providing new content [22]. This requires KSR to partner with broadcasters, event-organizers and the entertainment industry in general. Indeed, existing SDARS operators may well be some of the best partners to provide some of the new content. In building this business, we see that a lot of effort has to done in advance of servcie launch, so that the consumer see the value right rom day one.

7.2 Market Analysis

What is the size of the addressable market for such a service? The size of the market can be partially answered by knowing the population within the service area, and making an assumptions about market penetration, although it is interesting that Australians have more than 4 radios per household, so a one-to-one assumption is pessimistic for the home & portable market. In our approach, we choose a low subscriber growth to show that even under such conditions a profitable business can still be sustained. This is acceptable at this concept phase, but would have to be substituted by well designed market surveys.

In our analysis, we select two market sectors;

- The in-vehicle entertainment market.
- The home and portable radio market – portables and Hi-Fi stand-alone receivers.

7.2.1 In Car Market

According to the Australia 2001 census [20], there are approximately 12 million vehicles registered in Australia. Figure 17 shows the breakdown by vehicles type.

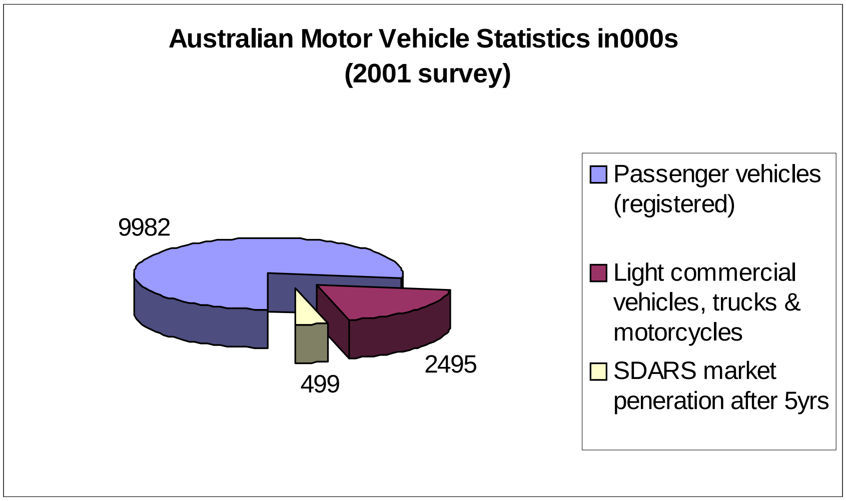

FIGURE 17. Australian Vehicle Statistics [20]

Nealry ten million are passenger vehicles. Taking a conservation approach, we assume the following; i) a flat population growth of vehicles, ii) a 5% market penetration in the first five years of operation resulting in 0.5 million for new and existing cars combined, iii) a 10% ceiling of the addressable market exists irrespective of time, receiver cost or programing content or expansion of service area, and, iv) 1 in 5 subscribers use a hybrid car/home receiver.

Assumption 1 - 500,000 receiver sales in five years for in vehicle sales.

The ability to attract and retain customers depends upon the programming content, and reducing the financial and installation barriers for subscribers. Also we are assuming; zero churn rate, static growth in market size, and no competition from equivalent sources of entertainment.

7.2.2 Home and Portable Market

The second target market are subscribers that would listen to the service at home or in a portable location, at the beach or a picnic. Establishing the market size of these subscribers relies first upon understanding the listening trends of Australians in their homes. Also how SDARS would fit in to the entertainment sources that Australians already have such as televisions, video-recorders, Hi-Fi, Internet. Understanding the market requires careful analysis of current subscriber habits, new trends and the price elasticity of the SDARS service & radio. Also the *willingness* to purchase is not the same as the *capability* to pay.

For the purpose illustrating our concept, we have assumed the following.

Of approximately 20 million Australians, we take only those in employment (9.3 million) and assume that only those that whose wages exceed the median wage level would be *capable* to purchase a radio and subscribe to the service - that's 5.12 million [21]. Of this group we assume that only 1 in 5 are interested in the service at home (1.02 million) -figure 18.

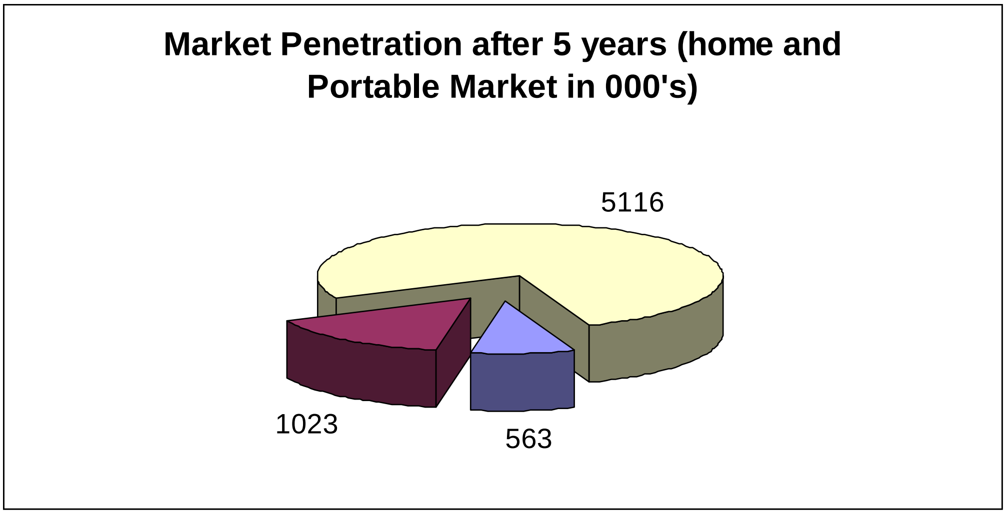

FIGURE 18. Size of addressable Home & Portable market

We further speculate that it would be possible to penetrate only half of this market in 5 years of service (0.56 million), but we subtract the 1 in 5 subscribers that use the hybrid home /car receiver.

<u>Assumption 2- 460,000 home receivers in five years</u>

Combining both market segments produces a maximum subscriber base after 5 years of 0.5 million (mobile) plus 0.46 (home-portable) – 0.96 million or 4.8% of the current population - its a simplified way of estimating that is appropriate for our concept.

7.3 KSR Business -forecasting revenues

KSR is an Australian public, limited company located in Australia whose core competencies are;

- Business to Consumer marketing and sales of radios and subscription services
- Business -Business sales of radio channels to broadcasters and content providers
- Operation and maintenance of specialist satellite networks
- Service provider functions, including control radio channel menus.
- Engineering & project management for planning, building and expanding the Satellite/ terrestrial networks

KSR has two types of customers; i) the broadcasters that wish to broadcast radio programs, special events, news and advertising throughout Australia, ii) radio listeners that are willing to pay a subscription fee to hear new radio entertainment both at home or in the car. KSR is not a broadcaster but it is responsible for meeting the expectations of the marketplace, and therefore it controls the overall content of the service. The structure of the company is shown in figure 19.

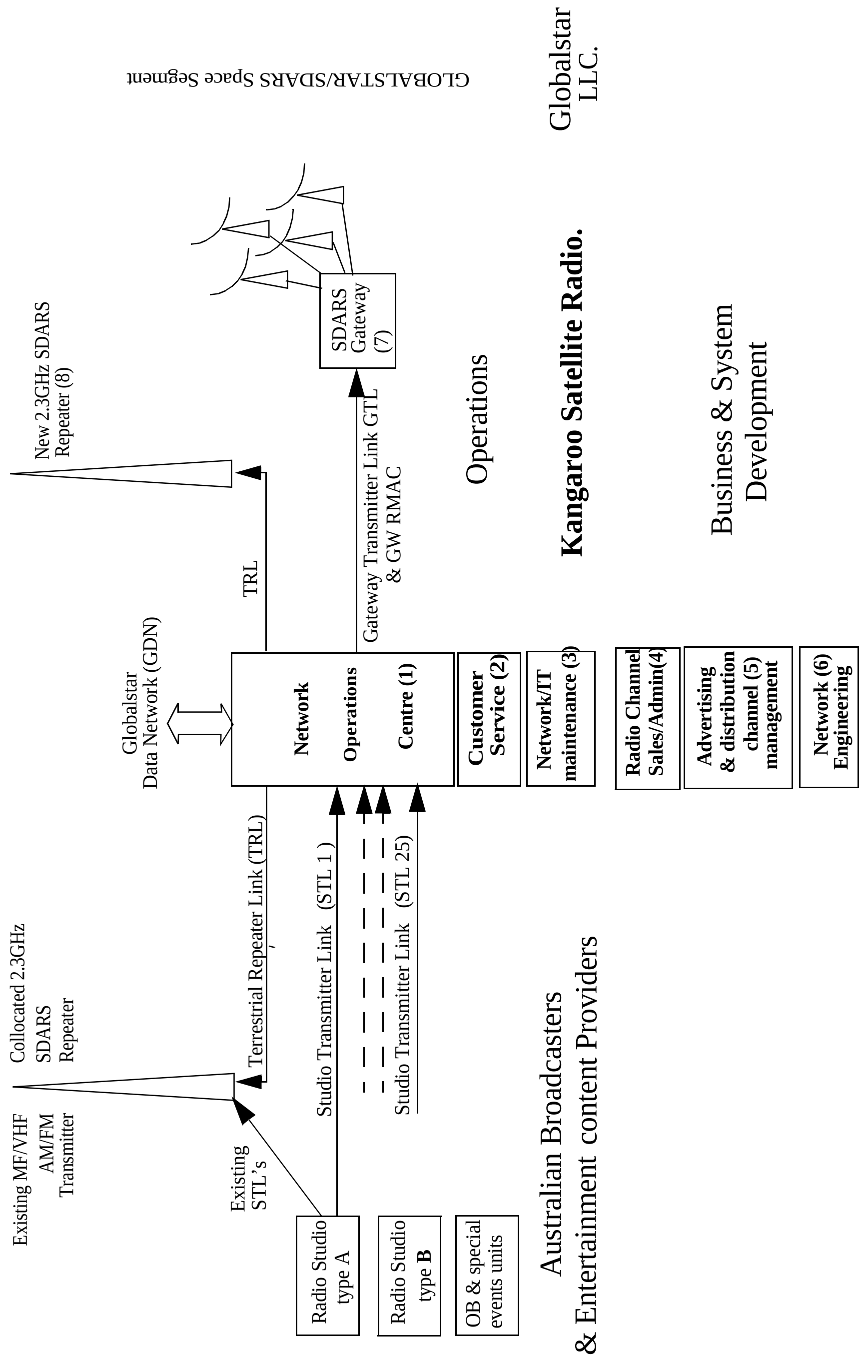

FIGURE 19. Structure of Kangaroo Satellite Radio

To test a business concept, we generated expense/revenue vs. time spreadsheet, and built in a growth model for subscriber adoption.

The following parameters were input to the model;

1. Approx $17 million is needed for Engineering development and to start the company including acquiring the network operations center. 40% is financed over 15 quarters at 3%, and the remainder is financed through an sales of shared via an IPO and these funds are used for almost all of the start-up expenses.
2. We use a power law for the subscriber growth with index 1.3 and reaches the market assumption of 960,000 subscribers in Q20 (year 5)
3. Other parameters are taken from; table 4 for revenues, table 5 for operating expenses and table 6 for the development expenses.

TABLE 4. KSR Sources of Revenue

Revenue source	**Frequency**	**value**
Subscription fees	market driven-960,000 in 5years	$10/month
Activation fee	once per subscriber	$15
Radio Channel lease fee	once per month per channel	Music - $10000 News - $8000
Special Event Channel lease fee	once per event 8 events per month assumed	$5000
Advertising fees	per min. per channel per 50000 subscribers. 6 mins per hour assumed Prime time (08;00-16:00) Off-peak (16:00-22:00) No charge (22:00-08:00)	$6 per min. $3 per min.
Advertising revenue per Qtr (Q1/Q8/Q16	$143k/$2.14M/$5.27M	
Subscriber/activations fees per Qtr (Q1/Q8/Q16)	$293k/$6.68M/20.6M	
Radio channel lease fees	$810k/qtr	

TABLE 5. KSR Operating Expenses

Expense	**value**	**notes**
Salaries	$497,500/mo	34 people
Marketing and other expenses	$80,000/mo	
Buildings, rent and administration	$100,000/mo	
Space-segment	$200,000/mo	

TABLE 5. KSR Operating Expenses

Expense	value	notes
Debt	$1,433,000/mo	
Total	$2,310,000/mo	

TABLE 6. KSR Non-Recurring Expenses

Type	Expense	Time frame
Engineering development, GW, SDARS mods, NOC acquisition	$11.95million	Q-6 to Q 0
SDARS collocated repeaters	$60m (20@$3 million each)	Q 8-Q 20
Licensing, permits, network ops facilities, HR, recruiting	$4.4M	Q -6 to Q 0
1/3 contribution to constellation replacement	$485M	Q15-Q30
Total non-recurring expense	$561.35M	

Later in the companies life, the first generation satellites will be nearing the end of life and need replacement. As one of the users of the system, KSR would be required to contribute to the replacement cost of the constellation, or launch its own satellites, perhaps a 3 satellite HEO constellation. The advantage of staying with the LEO constellation is that the replacement costs can be shared within the Globalstar user community and this maybe the lowest cost approach, but a performance compromise. Being a partner in the replacement program also allows KSR to tailor replacement satellites for SDARS use within the constraints of existing MSS users. The business model accounts for this by subtracting a satellite contribution element starting after Q15 and lasting for four years. The total contribution is estimated at $485m which represents a maximum contribution of 1/3 of the cost of replacing a 56 satellite constellation).

7.3.1 Kangaroo Satellite Radio - Forecasting Incomes

The output from the business model, revenue minus expenses over time before any taxes is shown in figure 20. Points A, B and C are major cash flows at KSR. Point A looks flat because the 60% of the development expenses ($10.2m) are raised through the IPO sales the remainder is financed over the next 15 quarters. Point B suppresses the growth curve because the repeaters are being deployed in urban areas. Point C takes a major chunk out of the income for the contribution of the replacement satellites.

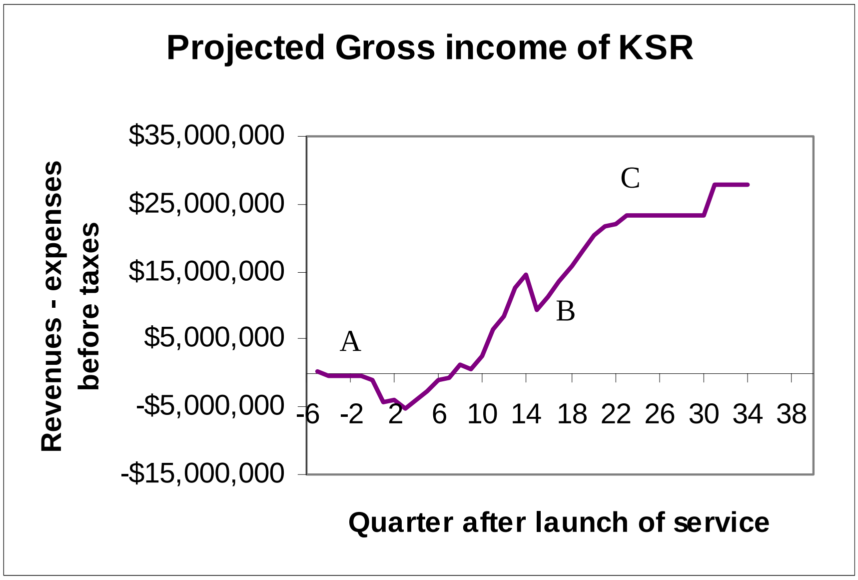

FIGURE 20. Gross Income from Fictitious Kangaroo Satellite Radio (KSR) Company

Within the limits of the business and market assumptions, the simplified model shows that a profitable business could be built, around selling radio radio channels and charging a small fee to carry advertising.

7.3.2 Uncertainties

There are a number of uncertainties that affect the business model, they are;

- Obtaining a private operating licence from the Australian Communications Authority at a reasonable cost.
- Securing a business agreement with Globalstar for monthly lease of the constellation throughout the required service area.
- Securing the agreement to modify the SDARS technology.
- Alternatives to SDARS, for example the use of the in-car hard disk recorder that can hold many hundreds of songs and play them in configurable play lists from the in-dash radio.

8.0 Regulatory Issues

Globalstar is currently licensed in many countries as a Global Mobile Personal Communication Service (GMPCS) and uses the band 2483.5-2500MHz which is allocated to

- FIXED
- MOBILE
- MOBILE-SATELLITE (Earth-Space)
- RADIO LOCATION and RADIODETERMINATION –SATELLITE services.

This band is coordinated at the signal levels and frequencies that can be produced by the Globalstar constellation. When using Globalstar for SDARS, the same power, approximately the same power flux density, and the same band of frequencies would be used - 2483.5-2500MHz. The SDARS application uses a slightly different frequency plan which extends closer to the edge of the assigned bands, making the requirement to keep out of band emissions under tight control, so it may not be possible to use the 16 channel plan discussed earlier so the number of channels may have to be reduced to 15.

Change the use of the band would have to be considered by the Australian Communications Authority, taking in to account the existing licencees, benefits that this could bring to Australian broadcasters and their listeners, and possibly re-planning of the S-band spectrum plan. While the ACA are responsible for radio spectrum management at the national level, these bands are coordinated internationally via International Telecommunications Union (ITU) to accommodate a number of systems. Iridium and Globalstar have agreements on the use of certain frequencies at S-band in regions around the world, including Australia, so this would have to be carefully considered, as would the protection of users in the adjacent bands within Australia.

We recognize that the bands 1452-1492MHz and 2535-2655MHz have been allocated by the International Telecommunication Union at WARC 92 in all ITU regions for the Broadcast Satellite Service (sound). The original intention of this allocation was to set aside bands, globally for broadcasting from geostationary satellites and it is questionable as to whether these allocations should be strictly applied to regional LEO satellite system like Globalstar which has already been coordinated. This is often a complicated matter, especially in some countries like the USA where the FCC regulates the use of the bands based upon its use for a particular service. In Australia, we understand that the ACA view is different in that it allows operators, within the technical and operational conditions of their licence, the flexibility to offer what type of service they choose based upon new applications or changing customer demand.It therefore seems likely that the ACA will consider an alternative use of the mobile satellite services for satellite radio broadcasting favourably.

Also, the Australian Broadcasting Association regulates all forms of broadcasting by applies certain rules of the Broadcast Act to different types of broadcasting situations, so it would depend upon how a new business venture was structured to what the regulatory environment would apply.

9.0 Summary

We have presented a technical and business concept that shows, in principle that it it feasible to use Globalstar for satellite radio broadcasting. We have not done any detailed calculations so we can't be sure about the number of channels; neither do we know how feasible it would be to change the SDARS receiver - but we don't think these issues are show-stoppers.

Given successful partnerships with Globalstar and the SDARS community, and the desire to merge the technologies in a cost-effective and timely fashion, a sustainable business looks possible.

For the SDARS community, involvement in this type of a venture would allow them to adapt their technology and services to address small markets than cannot afford new SDARS satellites, but nevertheless would be willing to subscribe.

For Globalstar and its partners, a larger and constant revenue stream which SDARS can provide would no doubt be welcomed, and for the existing Globalstar subscribers the prospect of moving to IRIDIUM appears acceptable.

Last, but not least, Australian broadcasters, radio and broadcast regulators and those involved in Australia's decade-long plan to implement digital audio broadcasting, will be excited about another technology that can help them reach that goal.

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