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CHAPTER 1

1. INTRODUCTION TO WLL

Features Discussed

- WLL Techno- Economical positioning
- WLL in Pakistan. Choice between GSM and CDMA
- Conclusion of Discussion

1.1 WIRELESS LOCAL LOOP TECHNO-ECONOMICAL POSITIONING

Wireless local loop (WLL) technologies are to large extent well-established and technically proven solutions for providing basic voice services to end customers. WLL networks connect subscribers to the public switched telephone network (PSTN) using radio signals as a substitute for copper lines for all or part of the connection between the subscriber and the switch. WLL system includes cordless access systems, fixed cellular systems.

Traditionally the term WLL has been used for systems, which primarily provide basic voice services. There are also other WLL technologies utilizing higher bands, such as 3, 5 GHz, which are mainly used f0r providing fixed data access in urban.

WLL deployments are aimed at increasing teledensity. The need to utilize wireless technologies as a substitute for traditional copper based solutions in order to increase teledensity stems from copper based solutions being often too expensive as well as too slow to deploy. This also applies to WLL technologies. The requirement for low cost is important especially in developing and low income regions where only the economically most feasible solution can create a competitive advantage. The choice of technology therefore used is directly affected by the governing economic factor.

1.1.1 Wll Developing Towards Limited Mobility

The latest developments in WLL have been towards adding limited mobility to the service, which has brought GSM and CDMA based solutions to the centre of attention. In the limited mobility scenario, the WLL handset can be used within the coverage area of one base station or, by extending the mobility, within defined base stations which could be located in two different locations for example, the terminals do not make handovers when changing between bas stations, so there is not real mobility as in true mobile networks. Vendors are interested in providing solutions which not only bring voice services to customers but also promise data and limited mobility. The proposition to add mobility to WLL offering is, however, not straightforward.

1.2 WLL SPECTRUM ALLOCATION AND TECHNOLOGY CHOICE-GSM or CDMA?

Due to increasing demand for limited mobility, new WLL networks are often based on GSM or CDMA technologies. From purely technological perspective the comparison between these two designs is difficult, if not impossible to perform. The complexity of the assessment is due to the fact that feasibility of a particular design is almost always case specific and there are several factors besides network technology affecting the decisions in the context of WLL implementations a factor is the availability of spectrum. Because of increasing demand, the frequencies most suitable for providing mobile services have been to a large extent allocated. As a result, bands such as 450 MHz have been brought forward as an alternative spectrum resource.

1.2.1 The risks of utilizing non-harmonized spectrum

The spectrum allocated for wireless local loop services mobility is located primarily in the 800/900 MHz bands Higher spectrum dedicated for mobile systems such as 1800/1900 is also suitable for providing WLL services, but as with other systems deployed in the bands, the optimal environment is urban, not sparsely populated rural areas in which the lower 800/900 MHz propagation model is more suitable. The widespread global use of the 800/900/1800/1900 spectrum combined with over 1.2 billion mobile terminals operating on these bands guarantee that these spectrum allocation will remain globally. Despite the fact that networks have been operational for some time now, there are still only three handsets models available for end users. For such a small market I, risk of infrastructure vendors scaling back investments on system development is apparent and could lead to a situation where no support or replacement parts for networks are available. The risk is further by the limited number of CDMA 450 infrastructure manufactures as there are currently only five companies providing equipment for this band namely Huawei, Hyundai, Syscom, Lucent Technologies, Nortel Networks and ZTE. Other more obscure problems related to the use of non harmonized spectrum have lead to network downtimes.

450 MHz band feasibility for offering advances mobile services has not been proven

The most fundamental question regarding the usage of the 450 MHz band is whether the frequency can be used to provide more than fixed line replacement services for end users. In the short term the answer might seem affirmative, but there are several issues that have not been resolved. Based on basic radio propagation characteristics, the 450 MHz band provides a 10 to 20 time coverage area than higher bandwidths. The drawback, however, is that the likelihood that the network performance is severely decreased and its management becomes more complex is higher. An example of such a scenario is a CDMA network in the 450 MHz band when loaded near the maximum capacity. Using such configuration, the user experience with both voice and data can deteriorate and is highly dependant on the user's location in the network. This can occur because the better propagation characteristics of the 450 MHz band allow larger cells, which make the network more sensitive to load increase as well as complicate the network management significantly. A possible solution to solve the problem would be limitation of the usable capacity or of the data rates per user. This is hardly an acceptable route in the long run because it means that the capacity of the network is not being utilized to the fullest. These issues support the selection of higher frequency, especially if data service evolution towards 3G is considered.

In bandwidths above 800 MHz the choice between GSM and CDMA generally depends on non-technical factors.

In bandwidths above 800 MHz the technology selection differs case-by-case depending on the case specific needs and preferences. Both GSM and CDMA technologies have their advantages. CDMA is argued to provide better spectral efficiency and thus enables higher capacity and lower cost per subscriber. However, the same efficiency ca be achieved with GMS is it is deployed with Haft Rate speech codec (minor decrease in voice quality) and the network is planned with smaller re-use of frequencies (possible minor increase in dropped call rate).

On the other hand service development in CDMA is more fragmented that in GSM, in which the efforts are more standardized. This enables better service interoperability for the GSM users globally. An advantage of CDMA is the effective and straightforward data roadmap from basic vice services to 3G for the operators using harmonized spectrum.

1.2.2 Handset Pricing Is the Key Issue in Increasing Penetration in the Low Income Segment

A major factor influencing the WLL technology choice is the availability and price of handsets. The total cost for the users consist of service costs and handset costs, of which the latter is more significant, especially for users in the low-income segments. When estimating the total cost of providing mobile or limited mobility services the terminal costs are often forgotten, because the initial investment in network is much higher. In the long run when most of the network investments have been made, importance of handset pricing becomes clear.

1.2.3 Lower handset price and availability favors GSM

There is a significant difference in GSM and CDMA prices which is mainly a result of economics of scale in manufacturing as well as chipset prices. In general CDMA850 chipsets are approximately twice as expensive as GSM and as this makes approximately 50% production material costs, CDMA handsets are clearly more expensive that GSM to produce.

1.2.4 WLL positioning – Fixed line replacement instead of a mobile service

The important question regarding wireless local loop services with limited mobility is the positioning of the service. There are several issues, which need to be considered in order to achieve the objective of increased teldensity.

1.2.5 Wll Limited Mobility and Real Mobile Services Serve Different Needs

Basic WLL and mobile services may at first appear quite similar because the cost important service component, voice, is almost identical. This comparison often leads to confusion over the difference between the two systems. For **mobile services**, the key characteristic is mobility. In the broadest sense this means both the ability to free roam within the operator’s network and also on other operator’s network. This leads to high requirements for the network coverage because the users must be reachable practically everywhere.

For **Wireless local loop services** several of the characteristics are different because the purpose is to increase teledensity in specific areas. The service must support voice quality equal to that of the fixed line as well as to provide the interfaces and capacity needed to support devices for fax and data access. Since the WLL service is comparable to a fixed line service, there is no need for extended mobility. The price of the terminal has to be low, because combined setup and call charges must be cheaper that for a fixed line solution in order for the WLL service to make sense economically for the end user.

Unclear licensing terms cause disturbances in the market

Allowing WLL mobility to directly compete with mobile services with different licensing terms can cause disturbances in the working of the local telecom market. In India, unclear licensing has become a major issue and is affecting the interoperability of fixed and mobile telecommunications networks and in some cases disrupting services to end-users.

Positioning WLL technologies as a real replacement for mobile technologies carries a considerable risk of customers not being to utilize mobile value added services. While many systems can provide intelligent services such as call waiting and call tr5ansfer, several new services available on current mobile networks may be non interoperable in WLL networks. These services include for example SMS and advances messaging services such as MMS. The cost for local WLL operators developing and deploying similar but non-standardized services is high and service interoperability is mostly non-existing. In emerging markets the importance of basic voice service, however is far more important that add-on service availability.

Introducing WLL services as mobile has also led to disputes between mobile cellular operators and regulators. The Cellular operators Association has stated that the entry of WLL services has had a direct impact on their revenues. The cellular operators see the situation as dire, and with court cases still ongoing after three years

1.2.6 Teledensity Does Not Increase By Converting Urban Mobile Users to Wll Users

Countries which have awarded WLL licenses and where the technology has been positioned as an alternative to mobile technologies, may not achieve the increases in teledensity, which they had originally hoped for. There are several reasons why this may be the case, but especially the question of WLL operator’s motives seems to be a crucial one. As the WLL license terms are not as strict as for mobile licenses, there is no mandatory provisioning of services for rural areas. Instead, the WLL operators target the same customer segment as the mobile operator’s i.e. urban business and consumers. However, there are also a very limited number of cases where WLL operators have provided services in the rural areas, but only with the help of government subsidization. This begs the question whether the WLL operator’s business case is only feasible for the highest revenue bearing segments in the urban area. The viability of the WLL operator business case for the rural regions seems to be very difficult to justify. It seems that there is an imbalance between regulator’s objective and how WLL operators are responding to these objectives. This contradiction will not lead to increasing teledensity but may instead cause disturbances in the market, as has been argued in the previous sections.

Conclusion: WLL operator's business case viability has not been proven

Issues regarding the logic behind WLL operator's business case which have been discussed in the previous sections can be summarized as follows:-

- The regulators expect WLL operators to address a customer segment, which has yet not been served by the fixed line operators or mobile operators (to increase teledensity)
- This customer segment is typically the rural market in which fixed line and mobile services are often limited.
- The business case for a stand-alone WLL operator focusing on the low rural market only is less impossible with the current cost of the technology (mainly cost of handsets).
- As a result the only possible way for a standalone WLL operator has often been to exploit additional sources of revenue, which usually means trying to position WLL limited mobility services as an alternative to mobile operators, service offering in urban areas.
- This has resulted in serious disturbances in the local telecom markets and has had a negative impact on the effort to try to increase teledensity.

Therefore WLL should be deployed on a harmonized spectrum with the technology, that is most cost efficient to use taken into account both network and handset costs.

1.3 CASE STUDY: WLL IN PAKISTAN – CHOICE BETWEEN GSM AND CDMA

Pakistan is an example of a market where the potential of wireless local loop based services has not yet been tapped. Many of the aspects discussed in the first chapter of this paper can be applied in the Pakistan case. Of particular importance are coverage related WLL issues, because the distribution of population and wealth within the region is challenging from this perspective. Since there is no longer a telecommunication monopoly in Pakistan, the market is suitable for analyzing the potential of new wireless services.

1.3.1 Telecommunications market overview

Pakistan covers around 800,000 km^2 (around 3.5 times the size of the U.K) and is one of the ten most populous countries in the world with a population base of 149 million, of which approximately 67% lives in rural areas. The average income per capita is around USD 430.

Fixed line teledensity is low and rowing slowly

Until 31st December 2002 the Pakistan fixed-line telecom market was a monopoly for Pakistan Telecommunication Company Limited (PTCL). By the end of June 2002 they had installed around 4.3 million access lines of which 3.7 million were in operation. Besides PTCL, there are two organization created by the government that also provide access services. One is the National Telecommunication Corporation (NTC), which by the end of 2002 provided around72,000 access lines to the government and Defence Forces. The other one is the Special Communication Organization (SCO), which operates a network of around 92,000 lines (Jan 2003) in the more remote Northern Areas, as part of a special development program. The teledensity (number of operational telephone lines as a percentage of the population) in Pakistan was only around 2.4 percent by Jun 2002. The teledensity in the urban areas in naturally higher than in the rural area (5.8 percent compared to 0.8 percent). Comparing this figure to the 10 percent teledensity in Asia and the 17 percent globally shows that Pakistan is at the lower end of the scale.

Mobile telecom market is growing much faster that fixed-line market

As of the end of March 2003 Pakistan had slightly over two million noble subscribers divided over four mobile operators a shown in Table. This equals a penetration rate of around 1.4%, one of the lowest in the Asia-Pacific region.

Table Mobile Operators

Operator	**Technology**	**Commercial Launch**	**Subscribers**
PTML (U fone)	GSM 900	Jan-01	565,000
Mobilink	GSM 900	Aug-98	910,000
Paktel	D-AMPS	Nov-94	267,000
Pakcom (Instaphone)	TDMA	Dec-90/Nov-00	270,000

Although the mobile penetration rate is still quite low, the Pakistani mobile market is growing quickly, especially since the introduction of GSM in the middle of 1998. Moreover, if one compares the mobile growth, it can clearly be seen that mobile take-up is much faster. According to conservative estimates, the total number of mobile subscribers will surpass the fixed-line subscribers.

1.3.2 WLL market is still in its infancy

Some five years ago, in order to address the urgency of the shortfall of telecommunication access in the country, the Pakistan Telecom Authority (PTA) approved a franchise concept. This concept allows private WLL operators to collaborate with PTCL's infrastructure for expansion of the payphone network in the country. As a result PTCL, signed operations and maintenance (O&M) contracts with four interested parties, namely, TELECARD, WORLDCALL, TELIPS and PAK DATACOM.

For all four operators no particular areas were required to be covered. However, a general preference was given to rural areas and the operators were required to deploy their WLL payphone services according to the following three tiers. 30% of the lines should be deployed in urban areas, 30% in sub-urban areas and 40% in the rural areas. It was further agreed that these four operators were to keep 20% to 35% of the revenues in addition to the mark-up allowed on PTCL calling rates 11. From these four operators, currently only Telecard is offering a WLL payphone service, a so called Public Call Office (PCO). The other three operators are sitting on their O&M agreement. Telecard, having signed the O&M contract with PTCL already in May 1999, started offering their PCO service from May 2002 onwards. They offer their service in urban areas (in 22 cities by December 2002) where PCO installation is required, i.e. the target market is not home or office users but small shopkeepers. The rural market has not been tapped yet, because the business case in urban areas, where teledensity is also still very low, is much profitable than in rural areas. Telecard, using a CDMA 1900 network provided by Chinese Vendor ZTE has rolled out 125,000 lines, as per their contract with PTCL. Currently the system allows only outgoing calls to be placed, so no calls can be received on the WLL terminal, although this feature is expected in the (near) future. Currently there is only true WLL operator, the SCO. They have started telephone service in the remote Northern Areas through WLL as part of the "Northern Areas Telecommunication Uplift Project", in March 2000. By January 2003 the SCO had launched 17 WLL stations at 13 localities, totaling 2,050 WLL lines thus connecting villages to the rest of the world. In order to increase their WLL services, PTCL has recently issued a tender for additional capacity of 190,000 WLL subscribers to be provided mainly in rural areas. The offered WLL system should be based on CDMA 2000 x in 450 MHz and 1900 MHz spectrum. 450 MHz spectrum should be used in rural areas, while 1900 MHz spectrum should be used in the urban areas. However, if either 1900 MHz is not available at time of contract or if it is not cost effective compared to 450 MHz then PTCL may decide in favour of 450 MHz. The tender is for two regions and the bidders can bid for either or both regions and for either 450 MHz or 1900 MHz spectrum PTCL has also asked the bidders to include support for limited and full mobility. The latter is subject to permission by the PTA to use it.

1.3.3 Telecommunication in Rural Increasing

There are currently 50,588 villages in Pakistan, which have a population between 100 and approximately 7,000 inhabitants. So far out of these 50,568 villages only around 1,213 have been provided with telecom facilities. Mainly due to the fact that providing copper fixed-line services to those areas can be cumbersome, time consuming and above all is too expensive (approximately Rs.515,000 or USD 250 per subscriber). Therefore providing telecommunication in the rural areas has been a very important item on the PTA's agenda. This can be seen from the O&M contracts PTCL was allowed to sign with private WLL operators to increase teledensity and the SCO's WLL development program. In a recent consultation paper on providing telecom in the rural areas, the PTA suggests the following:-

1. The PCO's connected to the mobile networks and digital long range cordless telephones may be the most cost effective and practical solution in the immediate and short term.
2. WLL may be the next option as permanent solution in the long term.
3. Satellite communication may be as appropriate and practical solution for remote and inaccessible areas.

With the first suggestion already being deployed, the deregulation of fixed-line services from 1st January 2003 has provided the PTA with the opportunity to implement the second suggestion. To achieve this, the PIA proposes, through a consultation document, two types of licenses of fixed operators. One is Local Loop fixed telecommunication operator (LL), the other a long-distance and international (LDI) fixed telecommunication operator. The PTA suggests to issues three LL licenses for each of the 13 PTCL administrative regions, resulting in 39 licenses, using either in 450 MHz band or the 1900 MHz band. The process of awarding these licenses should be through "an open, transparent and competitive bidding process to pre-qualified bidders" and there will be "no floor price fixed in the bidding of local loop licenses". There will also be no limit of licenses to market entrants who meet the license requirements. However, nothing has been decided upon yet. The existing operators of telecommunication services would be permitted to retain their current licenses and O&M agreements with PTCL. They are also allowed to compete for a new local loop license. Moreover, in a recent statement the PTA stated that they "had directed the mobile phone operators to formulate their roll out plans for larger coverage of their services especially in the less affluent and needy areas so that a common man could get benefit from this facility". This should be viewed in the light of issuing two national two cellular licenses after the issuances of LL and LDI licenses are completed.

1.3.4 Wll Service Affordability Analysis

The potential market for telecom services in Pakistan can be analyzed by means of an affordability analysis, which takes into account the annual spending on telecommunication and the cost of telecommunication services. In the affordability analysis Pakistan has been divided into urban and rural areas. The objective is to assess the number of households, which can afford the service as a function to total cost of using the service.

The following basic assumptions have been made:-

- Division of entire population based on income into five classes in both urban and rural areas.
- 67% of the inhabitants live in rural areas.
- Expenditure is analyzed per household due to low income.
- Fixed line/mobile and WLL services available in urban areas and only WLL services in rural areas.
- Local and long-distance calling mix with shares of 90% and 10% respectively.
- Depreciation of mobile terminals 5 years.

The main observation which can be made from this discussion is that the highest income population is mainly in the cities with the difference to lower income segments being significant.

Due to Terminal Pricing CDMA450 cannot be afforded in Majority of Rural Area

When calculating the rural WLL potential based on affordability, the cost of GSM1900 and CDM450/1900 terminals have a significant impact on the affordability of the service. In order for a household to subscribe to a WLL service it should spend the following minimum amount per year for the given technologies:-

- For GSM1900 23 USD
- For CDMA1900 34 USD
- For CDMA450 55 USD

These values state that if; given a certain technology the user spends less than the given amount per year on WLL services alternative telecom services, such as public phone booths become more financially attractive. When comparing these minimum thresholds to the average spending on telecommunication services, it can be concluded that if CDMA450 handsets are not subsidized, the CDMA450 WLL service can only serve can only serve the highest wealth segment in urban areas. This makes the business case for the WLL operator using CDMA450 practically impossible unless subsidies are being used. The comparison therefore is focused on GSM1900 and CDMA1900.

The affordability of GSM1900 in low income areas is significantly better than CDMA1900

The GSM1900 overall market potential as terms of households is almost double in size compared to CDMA1900 due to lower terminal prices. Most importantly the rural area potential reachable with GSM1900 is almost eightfold. This is a very important distinction between the two technologies, because in order to truly promote the availability of telecom services in rural areas, the affordability of the service must be ensured. In order forCDMA1900to reach the same affordability threshold and therefore the same potential as GSM1900 the CDMA terminals must be subsidized in order for the CDMA WLL operator to be competitive.

The circumstances subsides for terminals in case of CDMA1900 are the direct consequence of higher terminal costs and add up to almost 5800 million over operating time of eight years. These subsides are significantly higher than the total network investments. As the subsides depend directly on the number of subscribers, estimating the total amount at an early stage is difficult and often leads to only network investment being compared when the technology choice is made. **Transmission cost and effective coverage affect the overall feasibility.**

Besides terminal consideration, there are also other factors, which have been assessed qualitatively in the versus CDMA analysis. The most important ones in the Pakistan case are the population distribution effect for coverage and transmission costs.

Area coverage versus effective coverage on rural area using 450 MHz band

The main argued advantage of using CDMA450 is the large achievable coverage and the expected cost per subscriber due to low number of base stations needed. Savings in cost per subscriber can only be achieved if the population is evenly spread throughout the area to be covered. If the population is concentrated around villages with varying and long distances between each other the advantages gained by larger individual base station coverage is limited, as is the case in Pakistan. Located near a specific village, most of the CDMA450base station’s coverage potential would be wasted, unless there is a second community within the base station’s range.

Transmission cost

The deciding factor for offering WLL services in rural area is often not the actual base station equipment price, but the transmission costs of connecting the WLL equipment to the nearest point of interconnection in the backbone network. Most rural areas in Pakistan are located far from the PTCL backbone, which it located mainly in Sand between major cities.

If no physical transmission is available in the vicinity of a village the transmission cost will drive the choice of offering telecommunication services. The choice of using GSM1900 orCDMA1900 radio access technology has therefore often less impact on the total network investment than expected.

1.3.5 Pakistan Case Conclusions

Pakistan provides an interesting case example of the economics of WLL. By looking at the service offering from the end users point of view in the form of an affordability analysis, the following conclusions can be drawn:-

1. Pakistan market potential for WLL service exists and is estimated to be11 million households by year 2011 if the most suitable of the compared technologies, GSM1900, is utilized.
2. Terminal price is the single most important factor affecting the overall feasibility of a WLL implementation. In this respect the total advantage of a GSM1900 solution

is clearCDMA1900 can only compete when substantial subsides are used to lower the handset prices.

3. Cost per subscriber of deploying CDMA450 should be 32 USD lower per household than GSM1900 in order to have similar market potential due to required handset subsides with current terminal prices. CDMA450 further cannot capitalize on better coverage if the population is not evenly spread and if the distances between villages are long.
4. With stagnating fixed line penetration, fast growing mobile services play a crucial role in advancing telecommunications in Pakistan. If WLL limited mobility services are positioned to compete with mobile services, a severe risk of harming the mobile operators and telecommunications development in the region will be the result.

1.4 CONCLUSION

Wireless local loop services with limited mobility present a potentially feasible technology for increasing in rural areas. The feasibility of the business case depends on several factors including the available spectrum, demographics and the required services. Regardless of the technology used, WLL limited mobility services should not be positioned as true services by means of regulation as this may severely interfere with the local telecommunications market. Fair and equal treatment of license holders should form the basis of policy considerations. In most cases the terminal costs form the largest cost component in providing the WLL services. If the technology choice is made based on network infrastructure and maintenance costs alone, the viability of the business plan cannot be guaranteed in the long run. Particularly difficulties in this perspective are technologies operating in non-harmonized spectrum such as the 450 MHz where interoperability issues and handset costs present unsolved problems. GSM based WLL currently offers the most cost effective overall proposition for the studies markets due to lowest priced handsets. The cost advantages are due to economics of scale in manufacturing which is the result of highest number of installed networks and end users worldwide combined with open standards.

CHAPTER 2

2. ACCESS TECHNIQUES

Features Discussed

- Access Techniques
- FDMA
- TDMA
- CDMA
- Comparison of CDMA with TDMA & FDMA Systems
- Advancement in CDMA Regime

2.1 ACCESS TECHNIQUES

Access/Digital technology offers the opportunity for improved transmission in cellular systems. This is due to powerful error detection and recovery techniques, which can be used to counter the debilitating effects of noise, fading and interference. Digital technology also provides the basis for security in the forms of encryption and authentication. Finally, digital technology requires less in the way of mobile transmission power, which increases battery life in portable mobile units.

Digital cellar technologies also offer for premises of effective data transmission via cellular services. Although their vocoders prohibit the use of conventional modems, recent extensions to standards provide low-throughout data traffic in either a circuit-switched mode or via digital control channel, pocket switched data services are also.

Before presenting the primary digital cellular technologies, understanding the basic differences between FDMA, TDMA and CDMA is essential. As depicted in Figure 2.1 a frequency division multiple access (FDMA) system, such as AMPS, separates individual conversations in the frequency domain-different conversations use different frequencies (channels). In this depiction, the frequency is represented by the vertical dimension and the time domain is represented by the horizontal dimension.

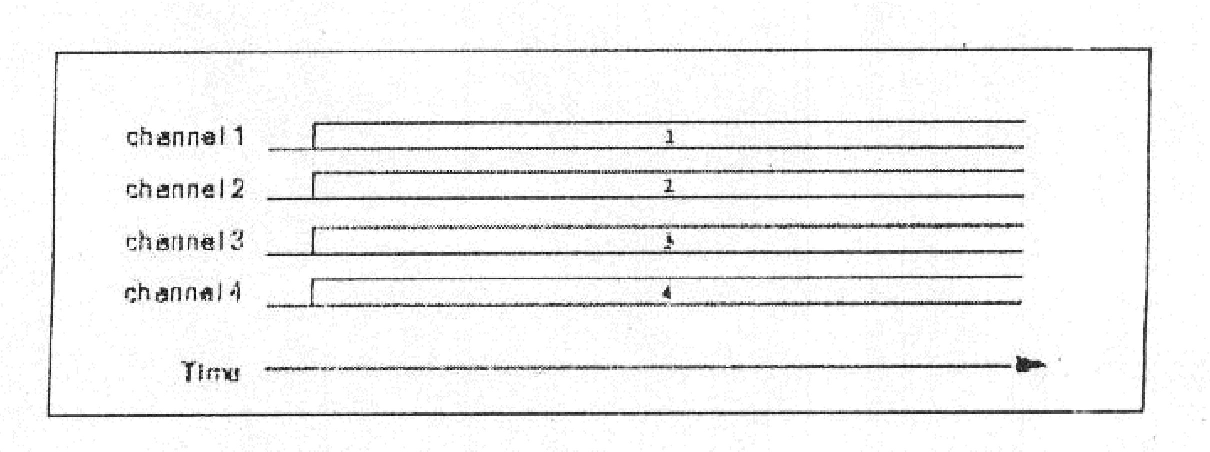


Figure 2.1: Time vs. Frequency for an FDMA System (e.g., AMPS)

Figure 2.2 shows how time division multiple access (TDMA) systems, such as IS-54/136, GSM or PDC, separate conversations in both the frequency and time domains; each frequency (channel) supports multiple conversations, which use the channel during specific timeslots. Typically there is a maximum number (3 in the example) of conversations which can be supported on each physical channel. Each conversation occupies a logical “channel”.

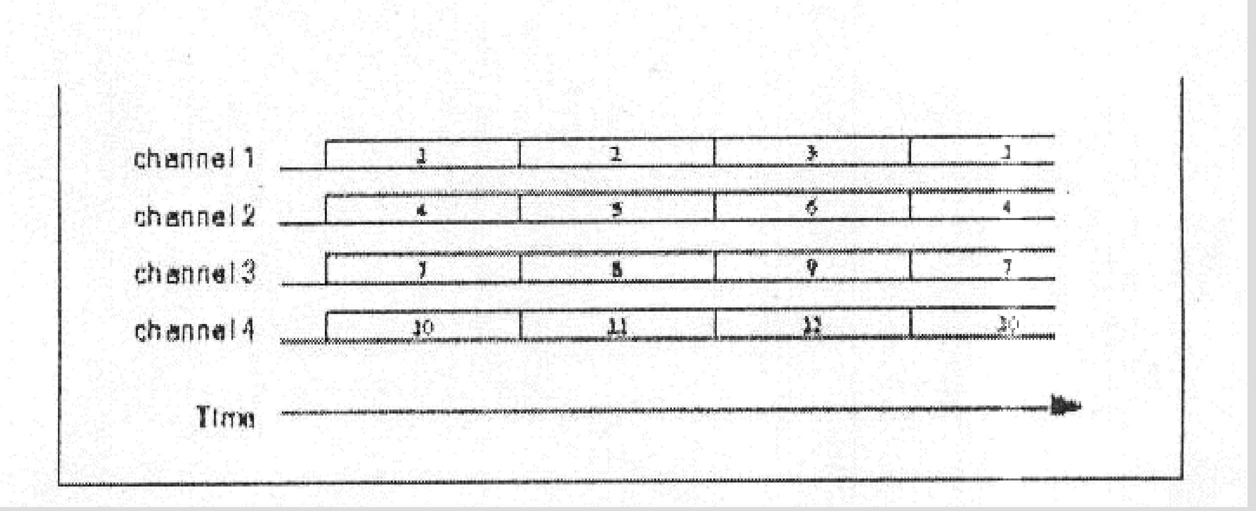


Figure 2.2: Time vs., Frequency for a TDMA System (e.g., IS54/136)

Figure 2.3 shows how frequency –hopping code division multiple access (CDMA) systems, such as spread spectrum wireless LANs, separate conversations in both the frequency and time domains. By rotating conversations through frequencies (channels) on a synchronized basis, each conversation experiences a variety of channel conditions. This rotation through the frequency set also tends to reduce the interference levels.

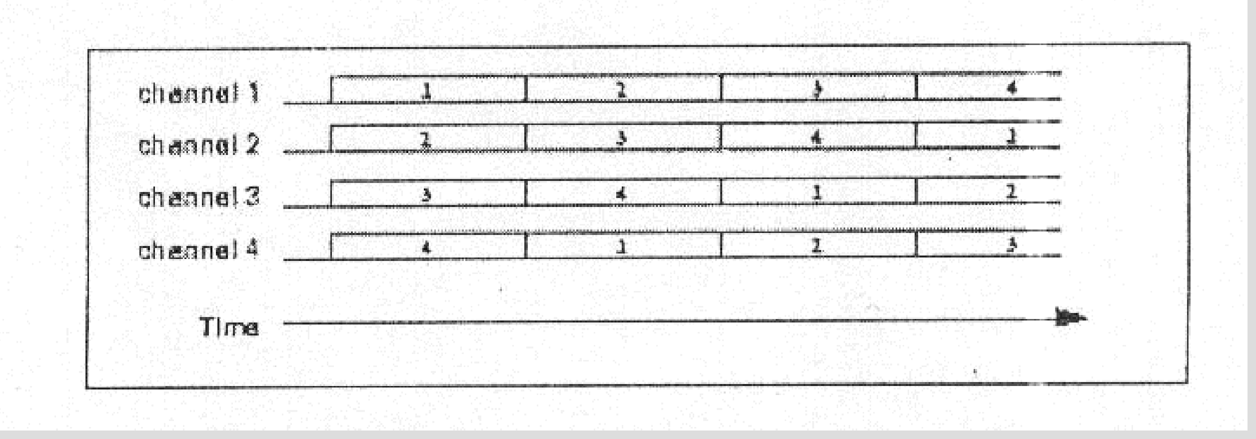


Figure 2.3: Time vs. Frequency for a FH CDMA System

Figure 2.4 shows how direct sequence CDMA systems, suchasIS-95, separate conversation on the basis of something entirely different than frequency or time. It’s hard to show in a time versus frequency diagram, but we will discuss it in upcoming section.

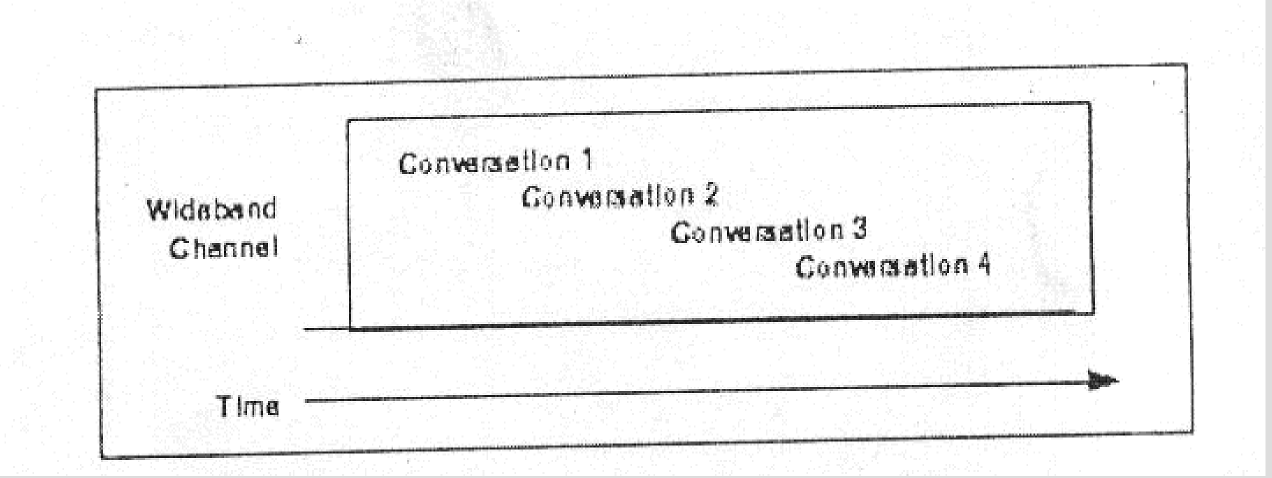


Figure 2.4: Time vs. Frequency for a DS-CDMA System (e.g., IS-95)

2.2 FDMA

Frequency division multiple accesses assign individual channels to individual users. These channels are provided on demand to users who request service. During the period of call no other user, uses the same channel. In FDD systems, the users are assigned a channel as a pair of frequencies on frequency is used for forward channel, while other is sued for reverse channel. The features of FDMA are:-

- The FDMA channel carries only one phone circuit at a time.
- If an FDMA channel is not in use, then it sits idle and cannot be used by other users to increase or share capacity. It is essentially a wasted resource.
- After the assignment of voice channel, the base station and the mobile transmit simultaneously and continuously.
- The bandwidth of FDMA channels is relatively narrows (30 kHz in AMPS) as each channel supports only one circuit per carrier. That is, FDMA is usually implemented in narrowband systems.
- The symbol of narrowband signal is large as compared to the average delay spread; this implies that intersymbol interference is low when compared to TDMA systems.
- Since FDMA is continuous transmission scheme, fewer bits are needed an overhead bits (such as synchronization and framing) as compared to TDMA.
- FDMA systems have higher cell site system cost as compared to a TDMA system.

- The FDMA mobile unit uses duplexers since both the transmitter and the receiver operate at the same time. This results in an increase in the cost of FDMA subscriber units and base station.
- FDMA requires right filtering to minimize adjacent channel interference.

2.3 TDMA

2.3.1 TDMA (IS-54)

Time Division Multiple Access or TDMA was initially defined by the IS-54 standard and is now specified in the IS-13x series. Because of its heritage as the original North American digital standard it's sometimes called digital AMPS or D-AMPS.

TDMA services were initially deployed during 1992 by Macaw, Southwest, Bell South and others. Although initial customer adoption was slow, there were an estimated half million TDMA subscribers by early 1995. This number is expected to grow dramatically in coming years, especially with new generation vocoders (which improve the perceived voice quality) Because TDMA physical channels are the same as the physical channels of AMPS, TDMA can be easily migrated into and coexist with AMPS systems in a dual mode manner.
TDMA subdivides each of the 30 kHz channels into 3 full-rate TDMA channels each of which is capable of supporting a single voice call. In the4 future, each of these full-rate channels will be further sub dividable into two half-rate channels, each of which-with the necessary coding and compression-could also support a voice call. Thus, TDMA could provide 3 to 6 times the capacity of AMPS traffic channels, with a corresponding gain in trunk efficiency. A similar calculation to that of previous sections yields an estimate of 3.5 to 6.3 times the capacity of an AMPS system.

Life AMPS, some of the digital channels are designated as control channels, called digital control channels or DCCH. These control channels serve the same purpose as in AMPS-paging and call control. Three forward-direction call setup control channels are used. The "A-stream" is used to page mobile with even-numbered MINs. The "B-stream" is used to page mobile with odd-numbered MINs. The "B/I-stream" indicates the busy/idle status of the reverse control channels, control of which is contested by mobiles wishing to originate calls.

Because of its time-division nature, by offsetting corresponding forward-and reverse-direction time slots, TDMA allows half-duplex phones to be used. This has the benefit of reducing cost and power consumption (i.e. battery size) of the mobile station, but with an increase in complexity due to the variable power envelope. It also allows the monitoring of control channels for out-of-band signaling during a call. Finally, the half-duplex operation allows mobiles to monitor the quality of channels used in neighboring cells in order to assist handoffs.

Originally, TDMA used parametric coding voice digitization, which is based on mathematical models of human vocal sounds. This prohibited the use of analog facsimile and modems due to the resultant distortion of modem signals (which are unlike human voice). Due to complaints of voice quality, the vocoders specified for TDMA have been upgraded with 1995 standards revision.

TDMA traffic channels use pi/4-DQPSK modulation at a 24.3-kbaud channel rate. This results in an effective 48.6 kbps data rate across the six time slots comprising one frame in the 30 kHz physical channels. TDMA standard specify RS-232 and AT-command set-capable mobile units which can used the system at a full-rate data speed of 9.6 kbps, which can be effectively doubled with V.42bis data compressions. A triple-rate data speed of 28.8 uncompressed (57.6 kbps compressed) is also specified. Gateways for facsimile and landline modems can be installed at MSCs by TDMA service providers.

A capability called short messaging service (SMS) has been specified in IS-136 to use the DCCH for short messages. This two-way service can deliver messages of up of 256 characters to the display on a subscriber’s phone. Similar services are also specified for CDMA and N-MPS systems.

A very recent packet data initiate has underway under the auspices of the TDMA Forum, the trade association for TDMA technology participants. The approach favored by the committee working on packet data services uses a dynamic time slot assignment with reservation algorithm which melds directly into the existing TDMA standard to provide CDPD-type services over TDMA channels.

In this proposed standard, all of the usual capabilities are supported in addition to variable bandwidth is potentially very large if enough TDMA channels are momentarily available for this purpose. Also specified is as efficient MAC layer ARQ mechanism plus the capability for a mobile unit to monitor both voice and data services simultaneously.

2.4 CDMA (CODE DIVISION MULTIPLE ACCESS)

2.4.1 Spread Spectrum Principles

SHANON Formula

C = Blog2 (1+S/N)

Where,

C is capacity of channel, b/s

B is signal bandwidth, Hz

S is average power for signal, W

N is average power for noise, W

It is the basic principle and theory for spread spectrum communications.

2.4.2 CDMA BASICS

Coding

CDMA, unlike FDMA and TDMA uses unique spreading codes to spread the base band data before transmission. The Signal is transmitted in a channel, which is below noise level. The receiver then uses a correlator to despread the wanted signal, which is passed through a narrow band pass filter. Unwanted signals will not despread and will not pass through the filter. Codes take the form of a carefully designed one/zero sequence produced at much higher rate of base band data.The rate of spreading code is referred to a chipping rate rather than bit rate.

2.4.3 TYPES OF CDMA

CDMA on the hand really does let everyone transmit at the same time. Conventional wisdom would lead you to believe that this is simply not possible. Using conventional modulation techniques, it is most certainly is impossible. What makes CDMA work is a special type of digital modulation called “Spread Spectrum”. This form of modulation takes the user’s stream of bits and splatters them across a very side channel in a pseudo-random fashion. The" pseudo" part is very important here, since the receiver must be able to undo the randomization in order to collect the bits together in a coherent order.

There are basically two CDMA based upon underlying modulation or spreading techniques. They are:-

- **Frequency hopping**
- **Direct sequence**

The details of these modulation techniques will be provided in the next chapter. Out of the two modulation techniques DSSS (direct sequence spread spectrum) is being mostly used throughout the World, also in Pakistan Chinese company ZTE is employing CDMA 2000 based system which use DSSS. There are three different kinds of codes involved in the process of spreading and dispreading the base band data, they are;

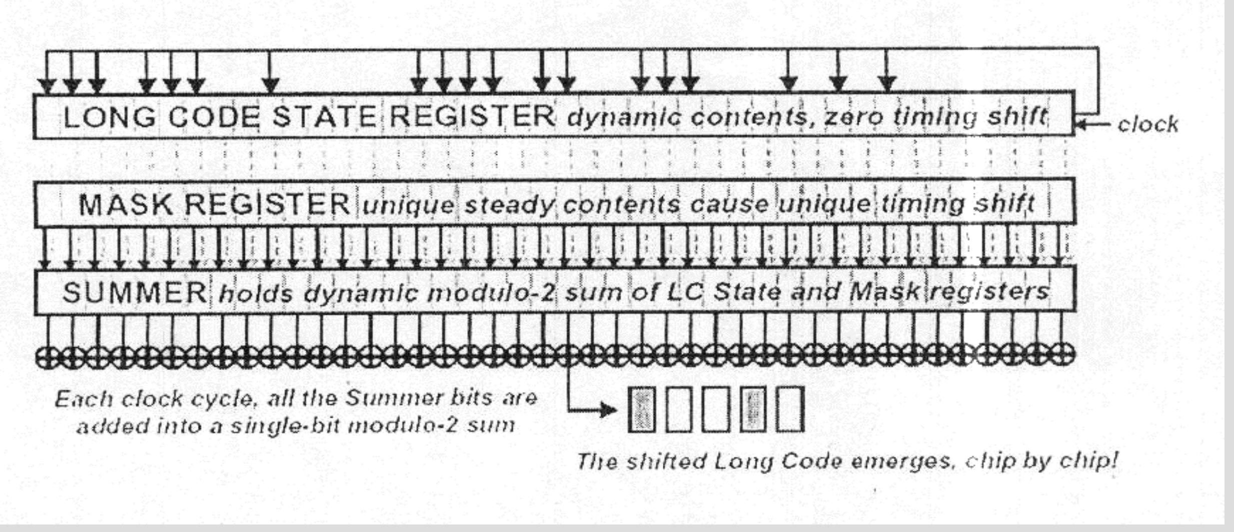
1. **PN long Code**
2. **Walsh Code**
3. **PN Short Code**

2.4.4 The Long PN Sequence

It is a privacy code, it is a long PN code implemented by a 42 stage shift register at the system chip rate of 1.288 Mcps. The code requires 41 days, 10 hours, 12 minutes and 19.4 seconds to complete. Every phone and BTS channel element has along code generator. A long code generator has three types of registers;

- LONG CODE STATE REGISTER, makes long code at system reference
- A MASK REGISTER, holds a user specific unique pattern of bits
- A SUMMER REGISTER, that contains sum of state and mask registers
- Each clock pulse drives the long code sate register to its next state. Each mobile station uses a unique User Long Code Sequence generated by applying a mask, based on its 32-bit ESN, to the 42-bit Long Code Generator which was synchronized with the CDMA system during the mobile station initialization.

- Portions of the User Long Codes generated by different mobile stations for the duration of a call are not exactly orthogonal but are sufficiently different to permit reliable decoding on the reverse link
- The access channel long code mask includes, Access channel #, paging channel #, BTS and pilot PN.



Thus a long code provides mutual randomness among different users

2.4.5 Walsh Codes

- 64 Sequences, each 64 chips long
- A chip is a binary digit (0 or 1)
- Each Walsh Code is Orthogonal to all other Walsh Codes
  - This means that it is possible to recognize and therefore extract a particular Walsh code from a mixture of other Walsh codes which are "filtered out" in the process
  - Two same-length binary strings are orthogonal if the result of XORing them has the same number of 0s as 1s

EXAMPLE:

Correlation of Walsh Code #23 with Walsh Code #59

#23 0110100101101001100101101001011001101001011010011001011010010110
<u>#59 0110011010011001100110010110011010011001011001100110011010011001</u>
XOR0000111111110000000011111111000011110000000011111111000000001111

Correlation Results: 32 1's, 32 0's: Orthogonal!!

Channel 0 = Pilot channel to assist coherent reception at mobile

Channel 32 = It is used for synchronization

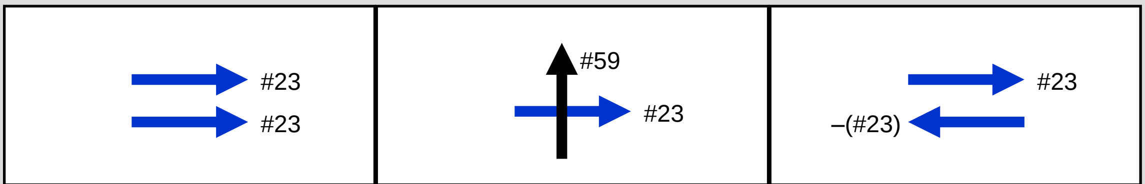
Channel 1 = Paging

That leaves a maximum of 61 channels for traffic use. The Walsh covers are applied at the chipping rate of 1.288 Mcps.

Correlation and Orthogonality

Correlation is a measure of the similarity between two binary strings

```
  Code #23 0110100101101001100101101001011001101001011010011001011010010110
-(Code #23) 1001011010010110011010010110100110010110100101100110100101101001
  Code #59 0110011010011001100110010110011010011001011001100110011010011001
```



PARALLEL	ORTHOGONAL	ANTI-PARALLEL
XOR: all 0s	XOR: half 0s, half 1s	XOR: all 1s
Correlation: 100% (100% match)	Correlation: 0% (50% match, 50% no-match)	Correlation: –100% (100% no-match)

Properties of the Walsh code

- When a Walsh code is XORed chip by chip with itself, the result is all 0's (100% correlation)
- When a Walsh code is XORed chip by chip with its logical negation, the result is all 1's (–100% correlation)
- When a Walsh code is XORed chip by chip with any other code or its logical negation, the result is half 0's and half 1's (0% correlation)

0	0	0	0
0	1	0	1
0	0	1	1
0	1	1	0

0	1	0	1
0	0	0	0
0	1	0	1

0	1	0	1
0	1	0	1
0	0	0	0

0	1	0	1
0	0	1	1
0	1	1	0

0	1	0	1
0	1	1	0
0	0	1	1

0	1	0	1
1	1	1	1
1	0	1	0

0	1	0	1
1	0	1	0
1	1	1	1

0	1	0	1
1	1	0	0
1	0	0	1

0	1	0	1
1	0	0	1
1	1	0	0

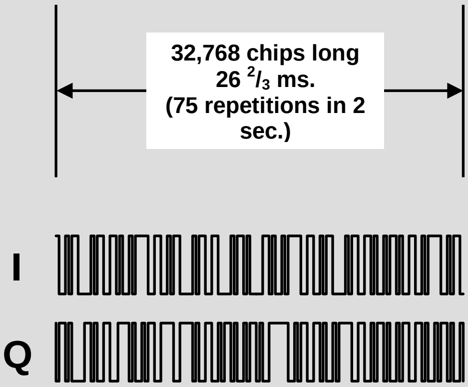
WALSH CODES

WALSH CODES

[illegible]

#	
0	0000000000000000000000000000000000000000000000000000000000000000
1	0101010101010101010101010101010101010101010101010101010101010101
2	0011001100110011001100110011001100110011001100110011001100110011
3	0110011001100110011001100110011001100110011001100110011001100110
4	0000111100001111000011110000111100001111000011110000111100001111
5	0101101001011010010110100101101001011010010110100101101001011010
6	0011110000111100001111000011110000111100001111000011110000111100
7	0110100101101001011010010110100101101001011010010110100101101001
8	0000000011111111000000001111111100000000111111110000000011111111
9	0101010110101010010101011010101001010101101010100101010110101010
10	0011001111001100001100111100110000110011110011000011001111001100
11	0110011010011001011001101001100101100110100110010110011010011001
12	0000111111110000000011111111000000001111111100000000111111110000
13	0101101010100101010110101010010101011010101001010101101010100101
14	0011110011000011001111001100001100111100110000110011110011000011
15	0110100110010110011010011001011001101001100101100110100110010110
16	0000000000000000111111111111111100000000000000001111111111111111
17	0101010101010101101010101010101001010101010101011010101010101010
18	0011001100110011110011001100110000110011001100111100110011001100
19	0110011001100110100110011001100101100110011001101001100110011001
20	0000111100001111111100001111000000001111000011111111000011110000
21	0101101001011010101001011010010101011010010110101010010110100101
22	0011110000111100110000111100001100111100001111001100001111000011
23	0110100101101001100101101001011001101001011010011001011010010110
24	0000000011111111111111110000000000000000111111111111111100000000
25	0101010110101010101010100101010101010101101010101010101001010101
26	0011001111001100110011000011001100110011110011001100110000110011
27	0110011010011001100110010110011001100110100110011001100101100110
28	0000111111110000111100000000111100001111111100001111000000001111
29	0101101010100101101001010101101001011010101001011010010101011010
30	0011110011000011110000110011110000111100110000111100001100111100
31	0110100110010110100101100110100101101001100101101001011001101001
32	0000000000000000000000000000000011111111111111111111111111111111
33	0101010101010101010101010101010110101010101010101010101010101010
34	0011001100110011001100110011001111001100110011001100110011001100
35	0110011001100110011001100110011010011001100110011001100110011001
36	0000111100001111000011110000111111110000111100001111000011110000
37	0101101001011010010110100101101010100101101001011010010110100101
38	0011110000111100001111000011110011000011110000111100001111000011
39	0110100101101001011010010110100110010110100101101001011010010110
40	0000000011111111000000001111111111111111000000001111111100000000
41	0101010110101010010101011010101010101010010101011010101001010101
42	0011001111001100001100111100110011001100001100111100110000110011
43	0110011010011001011001101001100110011001011001101001100101100110
44	0000111111110000000011111111000011110000000011111111000000001111
45	0101101010100101010110101010010110100101010110101010010101011010
46	0011110011000011001111001100001111000011001111001100001100111100
47	0110100110010110011010011001011010010110011010011001011001101001
48	0000000000000000111111111111111111111111111111110000000000000000
49	0101010101010101101010101010101010101010101010100101010101010101
50	0011001100110011110011001100110011001100110011000011001100110011
51	0110011001100110100110011001100110011001100110010110011001100110
52	0000111100001111111100001111000011110000111100000000111100001111
53	0101101001011010101001011010010110100101101001010101101001011010
54	0011110000111100110000111100001111000011110000110011110000111100
55	0110100101101001100101101001011010010110100101100110100101101001
56	0000000011111111111111110000000011111111000000000000000011111111
57	0101010110101010101010100101010110101010010101010101010110101010
58	0011001111001100110011000011001111001100001100110011001111001100
59	0110011010011001100110010110011010011001011001100110011010011001
60	0000111111110000111100000000111111110000000011110000111111110000
61	0101101010100101101001010101101010100101010110100101101010100101
62	0011110011000011110000110011110011000011001111000011110011000011
63	0110100110010110100101100110100110010110011010010110100110010110

2.4.6 Short PN Sequences

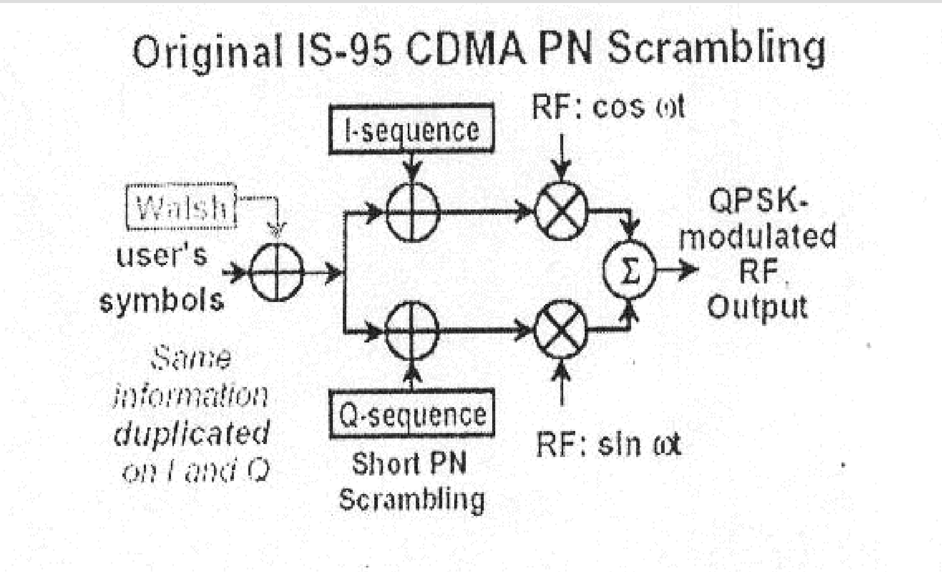


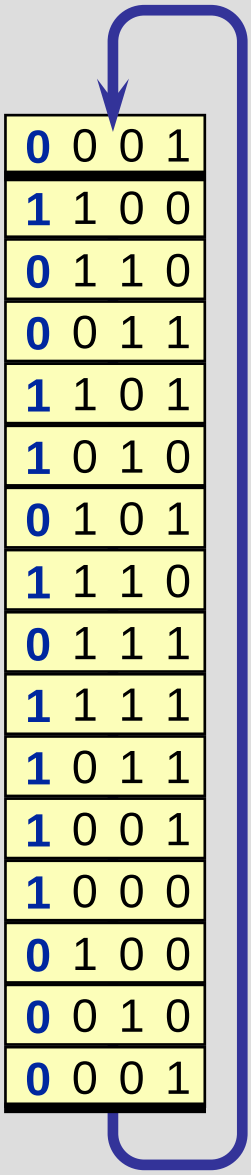
•The two Short PN Sequences, I and Q, are 32,768 chips long

•Together, they can be considered a two-dimensional binary "vector" with distinct I and Q component sequences, each 32,768 chips long.

•Each Short PN Sequence (and, as a matter of fact, any sequence) correlates with itself perfectly if Compared at a timing offset of a 0 chips.

•Each Short PN Sequence is special: Orthogonal to a copy of itself that has been offset by any number of chips other than 0).

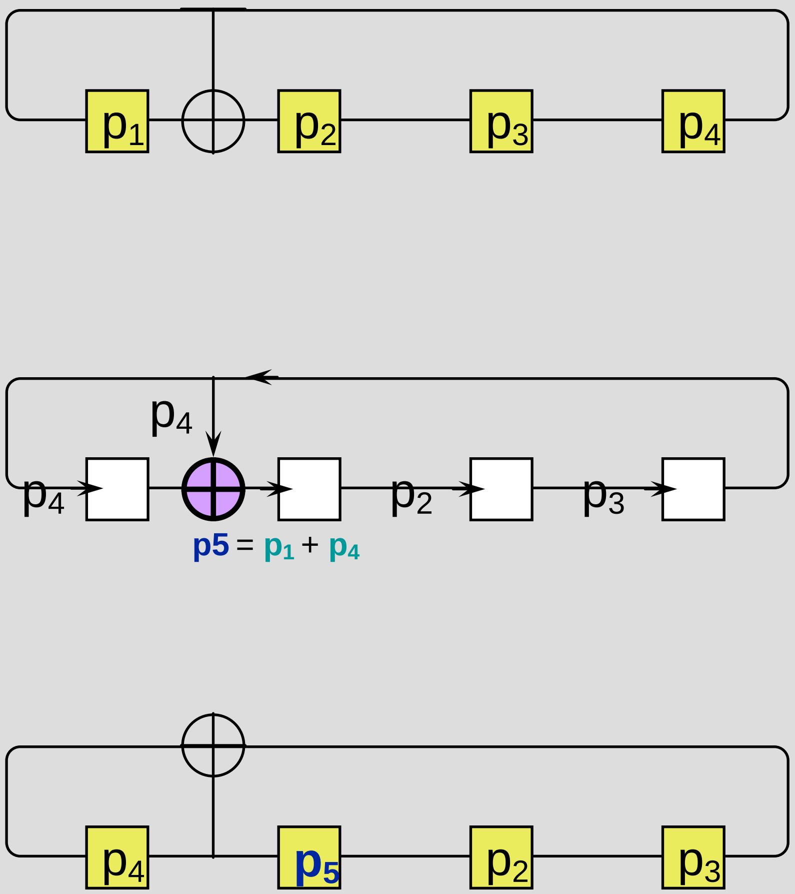




Short PN: 4-bits register example

The PN sequences are deterministic and periodic.

- The length of the generated string is 2n-1, where "n" is the number of elements in the register
- The number of zeroes in the sequence is equal to the number of ones minus 1



2.5 CDMA HANDOFFS AND CHANNELS POLLUTION

One of the terms you'll hear in conjunction with CDMA is "Soft Handoff". A handoff occurs in **any** cellular system when your call switches from one cell site to another as you travel. In all other technologies this handoff occurs when the network informs your phone of the new channel to which it must switch. The phone then stops receiving and transmitting on the old channel and it commences transmitting and receiving on the new channel. It goes without saying that this is known as a "Hard Handoff".

In CDMA however, every site are on the SAME frequency. In order to begin listening to a new site the phone only needs to change the pseudo-random sequence it uses to decode the desired data from the jumble of bits sent for everyone else. While a call is in progress the network chooses two or more alternate sites that it feels are handoff candidates. It simultaneously broadcasts a copy of your call on each of these sites. Your phone can then pick and choose between the different sources for your call, and move between them whenever it feels like it. It can even combine the data received from two or more different sites to ease the transmission from one to the other.

This arrangement therefore puts the phone in almost complete control of the handoff process. Such an arrangement should ensure that there is always a new site primed and ready to take over the call at a moment's notice. In theory, this should put an end to dropped calls and audio interruptions during the handoff process. In practice it works quite well, but dropped calls are still of life in a mobile environment. However, CDMA rarely drops a call due to a failed handoff.

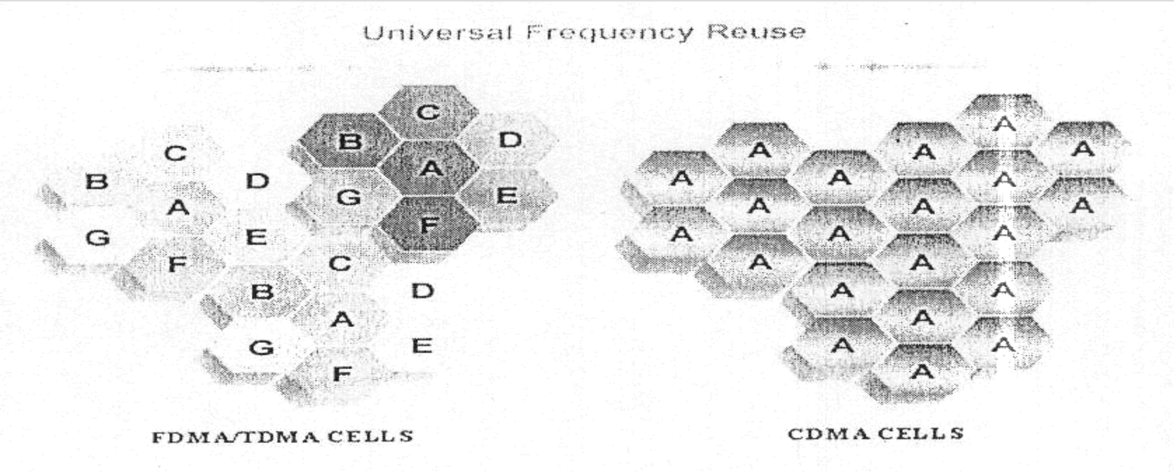
2.5.1 Channel Pollution

A big problem facing CDMA system is channel pollution. This occurs when signals from too many base stations are present at the subscriber's phone, but none are dominant. When this situation occurs the audio quality degrades rapidly, even when the signal seems otherwise very strong. Pollution occurs frequently in densely populated urban environments where service providers must build many sites in close proximity. Channel pollution can also result from massive multipath problems caused by many tall buildings. Taming pollution is a tuning and system design issue. It is up to the service provider to reduce this phenomenon.

2.6 COMPARISON OF CDMA WITH TDMA AND FDMA

2.6.1 Capacity and Frequency reusability

There are many advantages in using the CDMA air interface technique. Obviously, the major advantage is the capacity. CDMA takes advantage of the whole spectrum and allows multiple users on the same wise spectrum. The other advantages of CDMA relates to infrastructure and frequency reuse. Wirth FDMA and TDMA adjacent cells cannot use the same frequencies because of the interference that will occur. Since adjacent cells can't reuse the same frequency, planning and adding cells to a network a little difficult. With CDMA, all the signals are put in the same spectrum and are coded. Since the signals are coded, the system can distinguish the signals even though different signals occupy the same frequencies. The diagram below illustrates this. Assume each hexagon is a cell, and each letter is the frequency that is allocated to that cell. In the FDMA and TDMA systems, frequency “A” can’t be reused in the cells adjacent to it. In the CDMA system, since all the cells can be allocated the same frequency, frequency “A” can be reused anywhere. This is known as universal frequency reuse.



Inherently, CDMA has another benefit. CDMA happens to be a very private transmission. There are several aspects of the technology that contributes to its privacy. One aspect is associated with all wireless transmission; .Vocoding is voice encoding, which is a method of compressions. To be an efficient as possible all signals are compressed to use less of the bandwidth. Also, the signal is scrambled before it is transmitted; this transmission is coded with a 42 digit code. This provides 4.4 trillion permutations of this code. Along with several other codes that are required for effort corrections and reliability, these inherent aspects make CDMA a very private transmission. On top of the codes, encryption can be added to make a very secure technology.

2.7 ADVANCEMENT IN CDMA REGIME

The third generation (3 G) will be based on a modified CDMA air interface. 3G services take advantage of advanced W-CDMA broadband technology to offer users unparalleled freedom in the handling of mobile multimedia content such as voice, data and high-definition images. W-CDMA makes possible highly efficient, large-volume wireless communications, and it allows for the greatest possible clarity and stability, minimizing signal distortion, interference, and quality loss or bit errors due to fluctuating signal strength.

With W-CDMA, users transmit radio signals on a spectrum several hundred times wider than that used by conventional systems. Thus, the technology eliminates the need to divide frequencies into several bands; this spread-spectrum method maintains transmission quality and efficiency, even when data volume is extremely high. Another advantage of the wide frequency band is improved “rake” reception performance, since terminals gather signals reflected from tall buildings and mountain ranges and align them correctly.

W-CDMA gives users exceptionally stable communications while they are in motion as well, through simplified frequency management. Because one wide frequency band serves all cells, there is no need to allocate frequencies when adding new base stations. The use of a common frequency band produces highly stable communications since frequencies remain unchanged when users move from one cell to another, Stable communications, in turn, reduce interference on both base stations and terminals and bring the added benefit of lower power consumption.

W-CDMA also processes a wide range multimedia content, including full-motion video, very quickly a d efficiently. It does this both by taking full advantage of its wide frequency band and by employing a multi-rate transmission method that selects the most suitable transmission rate for data, based size and type.

2.8 A COMPARISON OF AMPS/FDMA, GSM, IS-54/TDMAA AND CDMA

Characteristics	**AMPS**	**DSM**	**IS-54**	**IS-95**
Bit rate	NA	270.8 kbps	48.6 kbps	1.2288 Mps
Carrier spacing	30 KHz	200 KHz	30 KHz	1250 KHz
Channels/Carrier	1	8 (16 Half-rate)	3 (6 Half-rate)	85
Channels	832	1000(2000)	2496 (4992)	
Time Slot	NA	577 ms	6.7 ms	NA
Time slot efficiency	NA	73 %	80 %	NA
Modulation	FM	GMSK	Pi/4-DQPSK	QPSK/OQPSK
Modulation efficiency (b/s Hz)	NA	1.35	1.62	
Channel Coding	NA	1/2-Convol	1/2-Convol	1/2-Convol
Speech Coding	NA	13 kbps RPE-LTP	7.95 kbps VSELP	CELP

CHAPTER 3

3. SPREAD SPECTRUM

Features Discussed

- What is Spread Spectrum
- Types of Spread Spectrum
- Pseudo-Noise Sequences PN
- Types of Spread Spectrum
- Application to Communication

3.1 WHAT IS SPREAD SPECTRUM AND WHY SHOULD WE USE IT?

Spread spectrum techniques originated in answer to the needs military communications. They are all based on modulation methods that greatly expand the spectrum of the transmitted signal relative to the data rate. During the last 23 or so years, many civilians' uses of spread spectrum were found. There is still growing interest in these techniques for the use in mobile radio networks and for satellite communication and positioning. The theoretical aspects of using spread spectrum in a strong interference environment have been known for decades. But it is only recently that practical implementations because feasible, mainly due to major advances in integrated circuits and DSP design. At first, spread spectrum technique4s were developed for military purposes and, therefore, their implementations were extremely expensive. Now, it is possible to develop relatively inexpensive spread spectrum devices for civilian us. These devices include cell phones, wireless data transmission devices such as wireless Ethernet and GPS navigation receivers.

A spread spectrum systems is one in which (1) the transmitted signal is spread over a wide frequency band, much wider that the minimum bandwidth required to transmit the information that is to be transmitted and where (2) the transmitted bandwidth must be determined by some function/code that is independent of the message and is known to both the transmitter and the receiver.

Most of the times the designers of communication systems are concerned with the efficiency with which the systems utilize the signal energy and bandwidth. In most systems these are the most important issues. In some cases, however, it is necessary for the system to resist external interference, to operate at low special energy, or to provide multiple access capability without external control, and to provide secure channel inaccessible to the outside listeners, In these cases it may be permissible to sacrifice some of the efficiency to enhance these features. Spread spectrum techniques allow accomplishing most of these tasks.

Spread spectrum is not about efficient utilization of bandwidth. However, it has many useful properties unavailable with other techniques. A spread spectrum signal can coexist with narrow band signals only adding a slight (often undetectable) increase in the noise floor that the narrow band receivers see and being itself unaffected by narrowband signals. One way to look at spread spectrum is that it trades a wider signal bandwidth for better signal to noise ratio. Frequency hop and direct sequence are the best-known spread-spectrum

Properties that make Spread Spectrum unique are:-

1. Jamming and interference resistance – especially to narrow-band offenders.
2. Signal hiding, low probability of intercept (LPI).
3. Good multi-path performance.
4. Code division multiplexing is possible.
5. Secure communication is easily implemented.
6. Improved special efficiency-in many applications (e.g. Cellular).
7. Easy to use for navigation/ranging.

3.2 TYPES OF SPREAD SPECTRUM

3.2.1 Direct Sequence Spread Spectrum (DSSS)

The most practical, all digital version of SS is direct sequence. It uses a locally generated pseudo noise code to encode digital data to be transmitted. That code runs at a significantly higher rate than the data rate. After a given number of bits the code repeats itself e4xactly. The speed of the code sequence is called the chipping rate, measured in chips per second (cps). Data for transmission is simply logically modulo-2 added (a XOR operation) with the faster pseudo noise code. The amount of spreading is dependent upon the ratio of chips per bit of information (which is the processing gain Gp for DSSS). The composite pseudo noise and data can be passed through a data scrambler to randomize the output spectrum (and thereby remove discrete spectral lines). A direct modulator is then used to double side and suppressed carrier modulates the carrier frequency to be transmitted. The resultant DSB suppressed carrier AM modulation can also be thought of a binary phase shift keying (BPSK). A short-code system uses a PN code length equal to a data symbol. A long-code system uses a PN code length that is much longer than a data symbol, so that a different chip patter is associated with each symbol.

Carrier modulation other than BPSK is possible with direct sequence. However, binary phase shift keying is the simplest and most often used SS modulation technique. At the receiver, the information is recovered by multiplying the signal with a locally generated replica of the code sequence. The PSK modulation scheme requires a coherent demodulation.

3.2.1.1 Basic Principle of Direct Sequence Spread Spectrum (DSSS)

Subscripts:

t stands for transmitted, r – received, s – symbol, c – chip.

Input:

Binary data d t with symbol rate R s = I/T s (=bit rate R b for BPSK)

Pseudo-noise code pn t with chip rate R c = 1/T c (an integer of R s)

Spreading:

In the transmitter, the binary data d t (for BPSK, I and Q for QPSK) is multiplied (XORed) with the PN sequence pn t, which is independent of the binary data, to produce the transmitted base band signal Tx b:

TX b = dt. pn t

The effect of multiplication of dt with a PN sequence is to spread the base band bandwidth R s of d t backbend bandwidth of Rc.

Dispreading

If pn r= pn t and synchronized to the PN sequence in the received data, than the recovered binary data is produced on d r. The multiplication of the spread spectrum signal rxb with the PN sequence pn t used in the transmitter is to dispread the bandwidth of Rx b to Rs.

The multiplier output in the receiver is then (since pn r = synchronized pn t):-

dr = rx b · pn r = (d t · pn t) · pn t

Since pn t. = +1 for all t

d r = d t

That is, the signal is accurately reproduced at the output.

If the PN sequence at the receiver is not synchronized to the received signal, the data cannot be recovered just like in the case where the sequence is wrong.

If pn r. pn t, then there is no dispreading action. The signal dr has a spread spectrum. A receiver not knowing the PN sequence of the transmitter cannot reproduce the transmitted data (it will basically produce yet another version of the spectrum spread of original signal – with a different code). The multiplier output becomes:-

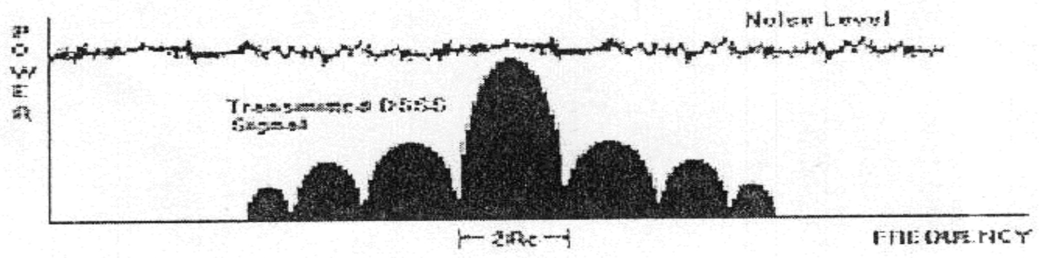
$$d_r = rx_b \cdot pn_r = (d_t \cdot pn_t) \cdot pn_r$$

In the receiver, direction o f the desired signal is achieved by the correlation against a local reference PN sequence. For secure communication in a multi-user environment, the transmitted data d_t may not be recovered by a user that doesn't know then the PN sequence pn_t used at the transmitted. Therefore;

Cross correlation $R_e(t) = \text{average}(d_t \cdot pn_r) << 1$ for all t is required.

This orthogonal property of the allocated spreading codes means that the out put of the correlator used in the receiver is close to zero for all except for the desired transmission.
The codes usable in this technique will be mentioned later.

The signals generated with this technique closely approximate noise in the frequency domain. The wide bandwidth provided by the PN code (high processing gain Gp) allows the signal power to drop the below noise threshold without loss of information. The spectral content of an SS signal is shown in figure below. Note that this is just the spectrum of a BPSK signal with a $\text{sinc}^2 x$ forms.



Spectral content of an DSSS signal

A typical commercial direct sequence radio might have a processing gain of from 11 to 16 dB, depending on data rate. It can tolerate total jammer power levels of from 0 to 5 dB stronger than the desired signal. Yes, the system can work at negative SNR in the RF bandwidth. Because of the processing gain of the receiver's correlator, the system functions at positive SNR on the based data.

3.2.2 Frequency Hopping Spread Spectrum (FHSS)

Frequency hopping is the easiest spread spectrum modulation to use. Any radio with digitally controlled frequency synthesizer can be converted to a frequency hopping radio. This conversion requires the addition of a pseudo noise (PN) code generator in select the frequencies for transmission or reception. Most hopping systems use uniform frequency hopping over a band of frequencies. This is not absolutely necessary, if both the transmitter and receiver of the system know in advance what frequencies are to be skipped. A frequency hopped system, unlike direct sequence one, can use both analog and digital carrier modulation and can be designed using conventional narrow band radio techniques. De-hoping in the receiver is done by a synchronized pseudo noise code generator that drives the receiver's local oscillator frequency synthesizer.

Frequency-hopping traces its toots back to World War II and it is interesting that one of the first patents on a method for synchronizing frequency hopping transmitters and receivers on submarines was held by the late actress Hedy Lamarr (an Austrian who had once been marr4ied to German munitions baron Fritz Mandl.

A pseudo-noise sequence pn t generated at the modulator is used in conjunction with a Mary FSK modulation to shift the carrier frequency of the FSK signal pseudo randomly, at the hopping rate R h. The transmitted signal occupies a number of frequencies in time, each for a period of time T h (=1/.R h, referred to as dwell time. FHSS divides the available bandwidth into N channels and hops between these channels according to the PN sequence. At each frequency hop time the PN generator feeds the frequency synthesizer a frequency work FW (a sequence of a chips) which dictates one of 3 n frequency positions f hi. Transmitter and receiver follow the same frequency hop patter. The transmitted bandwidth is determined by the lowest and highest hop positions and by the bandwidth per hop position DF ch. For a given hop, the instantaneous occupied bandwidth is identical to bandwidth of the conventional M-FSK, which is typically much smaller than W ss. So the FSSS signal is a narrow band signal, all transmission power is concentrated on one channel. Averaged over many hops, the FH/M-FSK spectrum occupies the entire spread spectrum bandwidth. Because the bandwidth of an FHSS system only depends on the tuning range, it can be hopped over a much wider bandwidth than a DSSS system. Since the hops generally result in phase discontinuity (depending on the particular implementation) a noncoherent demodulation must be used at the receiver's end. With slow hopping there are multiple data symbols per hop and with fast hopping there are multiple hops per data symbol.

3.3 PSEUDO-NOISE SEQUENCES PN

Random White Gaussian Noise

Although it appears as a real noise (because it is one) it is impossible to use it in real systems for spreading since it is not predictable at all. Use pseudo-random instead.

Pseudo-Random Noise

- Not random, but it looks randomly for the user who doesn't know the code.
- Deterministic, periodical signal that is known to both the transmitter and the receiver. The longer the period of the PN spreading code, the closer will the transmitted signal be a truly binary wave, and the harder it is to detect.
- Statistical properties of sampled white-noise.

Length of the code

- **Short:** The same sequence for each data symbol (N c · T c = T s).
- **Long:** The PN sequence period is much longer that the data symbol, so that a different pattern is associated with each symbol (N c. T c >>T s).

3.3.1 Properties of PN Sequences

Balance Property

In each period of the sequence the number of binary ones differs from the number of binary zeros by at most one digit (for Nc odd). When modulating a carrier with a PN coding sequence, one-zero balance (DC component) can limit the degree of carrier suppression obtainable, because carrier suppression is dependent on the symmetry of the modulating signal.

Run – Length Distribution – in order for the signal to appear and act like random.

Autocorrelation

The autocorrelation function for the periodic sequence pn is defined as the number of arrangements less the number of disagreements in a term by term comparison of one full period of the sequence with a cyclic shift (position t) of the sequence itself; For PN sequence the autocorrelation has a large peaked maximum (only) for perfect synchronization of two identical sequences (like white noise).

Frequency Spectrum

Due to periodic nature of the PN sequence the frequency spectrum has spectral lines which become closer to each other with increasing sequence length N c. Each line is further smeared by data scrambling, which spreads each spectral line and further fills in between the lines to make the spectrum more nearly continuous. The DC component is determined by the zero-one balance of the PN sequence.

Cross-correlation

Cross-correlation is the measures of agreement between two different codes pn i and pn j. When cross-correlation Re (t) is zero for all t, the codes are called orthogonal. In CDMA, multiple users occupy the same RF bandwidth and transmit simultaneously. When the user codes are orthogonal, there is no interference (ideally) between the users after dispreading and the privacy of the communication of each user is protected. In the real world, the codes are not perfectly orthogonal, hence the cross-correlation between user codes performance degradation (increased noise power after dispreading), which limits the maximum number of simultaneous users.

3.3.2 Types of pseudo-random sequences and their properties

M-sequence

Balance

For an m-sequence there is one more 1 and 0 in a full period of the sequence. Since all states are reached in an m-sequence, there must be 2 L-1s and 2 L-1-1 0s.

Autocorrelation

The autocorrelation of the m-sequence is – for all values of the chip phase shift t, except or the [-1, +1] chip phase shift area, in which correlation varies linearly from the -1 value to 2 L – 1 = N c (the sequence length). The autocorrelation peak increases with increasing length Nc of the m-sequence.

Cross correlation

Unfortunately, cross-correlation is not so well behaved as autocorrelation.

Security

The m-sequence codes are liner, and thus not usable to secure a transmission system. The linear codes are easily decipherable once a short sequential set of chips (2L+1) from the sequence is known.

Barker Code

The Barker code gives codes with different lengths and similar autocorrelation properties as the m-sequences. Mentioned since it is used in IEEE 802.11 implementation.

Gold Codes

A multi-user environment (CDMA in particular) needs a set of codes with the same length and with good cross-correlation properties. Gold code sequences are useful because a large number of codes (with the same length and with controlled cross correlation) can be generated, although they require only one “pair” of feedback tap sets.

Any 2-register Gold code generator of length L can generate 2 L -1 sequence (length 2 L -1) plus the two base m-sequences, giving a total of 2 L +1 sequences. In addition to their advantage in generating large numbers of codes, the Gold codes may be chosen so that over a set of codes available from a given generator the autocorrelation and the cross correlation between the codes is uniform and bounded. When specially selected m-sequences, called preferred m-sequences, are used the generated Gold codes have a three valued cross correlation. Predictable cross-correlation properties are very useful in an environment where one code must be picked from several codes which exist in the spectrum. Only parts of the generated Gold codes are balanced.

Hadamard-Walsh Codes

Walsh-sequences’ biggest advantage is their advantage is Orthogonality, this way we should be able to avoid any multi-access interference. The cross-correlation between any two Hadamard-Walsh codes of the same length (derived from the same matrix) is zero, when perfectly synchronized. There are, however, several drawbacks.

- The codes do not have a single, narrow autocorrelation peak – harder to synchronize.

- Since the codes are periodic, the spreading is not over the whole bandwidth; instead the energy is spread over a number of discrete frequency-components. This periodicity also causes problems with synchronization based on autocorrelation.
- Although the full-sequence cross-correlation is identically zero, this does not held for partial-sequence cross-correlation function. The consequence is that the advantage of using orthogonal codes is lost unless, again, the codes are perfectly synchronized.
- Orthogonality is also affected by channel properties like multi-path. In practical systems equalization may be applied to recover the original signal.

These drawbacks make Walsh-sequences not suitable for non cellular systems. One of the systems in which Walsh-sequences are applied is cellular CDMA system IS-95 (in Toronto area used by Bell Mobility and Telus Mobility).

3.4 PROPERTIES OF SPREAD SPECTRUM

The performance increase for spread systems (and probably for other wideband systems) is referred to as "processing gain". This term is used to describe the improvement in signal quality at the cost of increased bandwidth. The numerical advantage is obtained from Cluade Shannon's equation describing channel capacity;

C= W log 2 (1+ S/N)

Where C = Channel capacity in bits, W= Bandwidth in Hz, S= Signal Power, and
N = Noise Power

From this equation, the result of increasing the bandwidth becomes apparent. By increasing W in the equation, the S/N may be decreased without decreased BER performance. The processing gain (GP) is what actually provides the increased system performance without requiring a high S/N in the medium mathematically as;

G P = B W RF / R INFO

Where B W RF = RF Bandwidth in Hz and R INFO = Information rate in bps.

3.4.1 Performance in the presence of interference, Anti-Jamming Capability (AJ)

Assume the received signal rx b consists of the transmitted signal tx b plus an additive interference I (noise, other users, jammer…);

Rx b= tx b + I = d t · pn t + i

To recover the original data dt, the received signal Rx b is multiplied with a locallt=y generated PN sequence pn r that is an exact replica of that used in the transmitter.
(that is pn r = pn t and is synchronized). The multiplier output is therefore given by;

pn t. pn t = +1 for all t

The multiplier output becomes;

D r = dt + i · pn t

The data signal d t is reproduced at the multiplier output in the receiver, except for the interference represented by the additive term i · pn t. Multiplication of the interference I by the locally generated PN sequence means that the spreading code will affect the interference just as it did with the information bearing signal at the transmitter. Noise and interference, being uncorrelated with the PN sequence, become noise-like, increase in bandwidth and decrease in power density after the multiplier. After dispreading, the data component d t is narrowband (R s) whereas the interference component is wideband (R c). By applying the d r' signal to a base band LPF with a bandwidth just large enough to accommodate the recovery of the data signal, most of the interference component "I" will be filtered out. The effect of the interference is therefore, reduced by the processing gain (G p).

Narrowband interference

The narrowband noise is spread by the multiplication with the PN sequence pn r of the receiver. The power density of the noise is reduced with respect to the dispread data signal. Only 1/G p of the original noise power is left in the information base band (R s). Spreading and dispreading enables a bandwidth trade for processing gain against narrow band interfering signals. Narrowband interference would disable conventional narrowband receivers. The essence behind the interference rejection capability of a spread spectrum system the useful signal (data) gets multiplied twice by the PN sequence, but the interference signal gets multiplied only once.

Wideband interference

Multiplication of the received signal with the PN sequence of the receiver gives a selective dispread of the data signal (smaller bandwidth, higher power density). The interference signal is uncorrelated with the PN sequence and is left spread.

Origin of wideband noise

- Multiple Spread Spectrum users; multiple access mechanism.
- Gaussian Noise; There is no increase in SNR will spread spectrum. He larger channel bandwidth (Rc instead of Rs) increases the received noise power by G p. Gaussian noise is, actually the best jamming signal for SS if there is such.

Jamming

The goal of a jammer is to disturb the communication of his adversary. The goals of the communicator are to develop a jam-resistant communication system under the following assumption:-

- Complete invulnerability is not possible.
- The jammer may have priori knowledge of most system parameters, frequency bands, timing and traffic.
- The jammer has no a priori knowledge of the PN spreading code.

The anti-jamming property (AJ) results from the wide bandwidth used to transmit the signal. It follows from the Shannon's theorem for channel capacity – by purposely making the information-bearing signal occupy a bandwidth far in excess of the minimum bandwidth necessary to transmit it we gain enough space to counter the effects of noise (and also jammer etc). This also has the effect of making the transmitted signal assume a noise-like propagate through the channel undetected by anyone who may be listening. Spread spectrum is a method "camouflaging" the information-beating signal. Attacking spread spectrum systems.

- Spread spectrum signals can be easily jammed if the spreading sequence is known.
- If the sequence is known, a jammer can use;
    - Carrier frequency interference.
    - Spread spectrum interference.
    - Gaussian noise.
- Gaussian noise is most effective against sophisticated receivers.
- Interference causes errors for frequency hopper – some form of error-correction/ redundancy is required in order to withstand it.

The spread of energy over a wide band, or lower spectral power density, makes SS signals less likely to interfere with narrowband communications. At the same time, narrowband communications are less likely to cause significant interference to SS transmission. All SS systems have a threshold or tolerance level of interference beyond which useful communication ceases. This tolerance or threshold is related to the SS processing gain. The effectiveness of special spectrum's interference-rejection property has made it a popular military anti-jamming technique.

3.4.2 Probability of Intercept (LPI)

Spread-spectrum signals exhibit some usual but signal effects. Close to the transmitter, a spread spectrum signal may be observed readily on a conventional receiver. However, at a distance (50-100 miles) the signal may be noticed only with careful measurement. This result in a property called low probability of intercept (LPI). Some authors dispute the notion of LPI, saying that spread-spectrum signal energy is in fact intercepted by the receiving station's antennas and receivers; however, there is a low probability that the listener will recognize the presence of spread spectrum. The term, low probability of recognition (LPR), has been suggested in place of LPI.

This radical difference in signal strength between close-in and distant observers is quite logical. The power of a narrow-band signal is typically concentrated about a centre frequency; hence a conventional narrow-band receiver will be in position to collect much of the original power subject to path loss. In the DS spread-spectrum case, the same power sd distributed over a band of frequencies, giving less power per hertz. A narrow-band receiver can collect only as much distributed power as the width of its IF pass band, consequently, it registers a much weaker signal. A spread-spectrum receiver's pass band is quite wide, allowing it to receive the entire bandwidth containing the spread-spectrum signal. This power is concentrated by the dispreading process, making the output signal-to- noise ratio at least equal to the narrow-band signals. And, let's not forget that DSSS systems can work in negative SNR. Even if not, the shape of the spectrum of the transmission is quite unremarkable (FHSS is a bit worse in that sense and the shape of its spectrum is usually a dense rectangle…).

In the case of FH spread spectrum a full-power narrow-band carrier is hopped among many channels. The concentrated power of the carrier can be observed at a distance equal to that of a noon-hoping narrow-band signal. However, a conventional receiver will only catch a glimpse of the FH signal as it briefly visits the currently received channel. Low probability of intercept (LPI) can be achieved with high processing gain and unpredictable carrier signals when power is spread thinly and uniformly in the frequency domain, making detection against noise by the surveillance receiver difficult. A low provability position fix (LPPF)S attribute goes one step further in including both intercept direction finding (DFing) in its evaluation. Low probability of signal exploitation (LPSE) may include additional effect, e.g., source identification, in addition to intercept and DFing.

3.4.3 Fading and Multipath Resistance, RAKE receivers

In wireless channels there exists often multiple path propagation; there is more than one path from the transmitter to the receiver. Such multipath may be due to:-

- Atmospheric reflection or refraction.
- Reflections from ground and buildings.

Multipaths usually result in fluctuations in the received signal level (fading). Each path has its own attenuation and time delay. It is important to keep the direct path and reject the others. Assume that the receiver is synchronized to the time delay and RF phase of the direct path. The signals at the receiver can be from; the direct path, other paths, white noise, interference.

Multipath signals that are delayed by a period or longer relative to the desired signal (outdoor reflections) are essentially uncorrelated due to the properties of the spreading codes and do not contribute to multipath fading. The SS system effectively rejects the multipath interference like in the case of CDMA choosing only the earliest (i.e. direct signal).

A RAKE (the name is due to diagram that illustrates the concept resembling the garden rake) receiver implementation for direct sequence allows individual signal paths to be separately detected and then coherently combined with other paths. This not only prevents fading in most cases but also provides a path diversity effect resulting in more rugged links in terrestrial mobile communications.

3.4.4 Code-Division Multiplexing

Code Division Multiple Access (CDMA) is method of multiplexing (wireless) users by distinct (orthogonal or almost orthogonal) codes. All users can transmit at the same time, and each is allocated the entire available frequency spectrum for transmission. The result is a kind of a dedicated channel, one in which only the spread-spectrum signal using the same pseudo-noise sequence will be accepted by the spread-spectrum receiver. A two-party conversation can take place, or, if the code sequence is known to number of people, net-type operations are possible.

CDMA does not required the bandwidth allocation of FDMA, nor the time synchronization of the individual users needed in TDMA (actually, synchronization is needed quite often, but, fundamentally, systems can exist without it; Walsh code based systems need it since they are periodic and therefore have inferior autocorrelation behavior). A CDMA user has full time and full bandwidth available, but the quality of the communication decreases with an increasing number of users.

Correlation of the received base band spread spectrum signal rx b with the PN sequence of user 1 only de-spreads the signal of user 1. All other users produce noise N u for user 1. Only that portion of the noise produced by the other users falling in the information bandwidth [-R S, Rs] (not [-Rc, Rc]) of receiver, causes interference with desired signal.

Useful codes are:-

- Gold codes, Kasami codes (asynchronous CDMA)
- Hadamard-Walsh codes (synchronous CDMA)

3.4.5 Security

Besides being hard to intercept and jam, spread spectrum signals are hard to exploit or spoof. Signal exploitation is the ability of an adversary (or a non-network member) to listen into a network and use information from the network without being a valid network member or participant. Spoofing is the act of falsely or maliciously introducing misleading or false traffic or messages to a network. SS signals also are naturally more secure than narrowband radio communications. Thus SS signals can be made to have any degree of message privacy that is desired. Messages can also be cryptographically encoded to any level of secrecy desired. The very nature of SS allows military or intelligence levels of privacy and security to be had with minimal complexity. While these characteristics may not be very important to every day business and LAN (local area network) needs.

That property of the CDMA is believed to be one of the reasons CDMA cellular couldn't take off in Eastern Europe (another is the presence of GSM).

3.4.6 Near-Far problem

Each user is a source of interference for the other users, and its signal is received with more power, than that user generates more interference for the other users (and also severely diminishes the potential Orthogonality of the codes). It is important that the receiver gets the same power from each transmitter. The use of power control ensures that all users arrive at about the same power Prx at the receiver, and therefore no user is unfairly disadvantaged relative to the others.

3.4.7 Comparison of modulation methods

The best way to compare different SS modulation techniques is to list their advantage and disadvantage:-

Direct-sequence (PN) systems

(+) Out of the two modulation techniques DSSS has the best noise and anti-jam performance. It is the most difficult to intercept Fights well against multipath effect. Continuous spread of the transmitting, power, the narrowband interference is reduced by Gp, Good automatic rejection of multipath.

(-) It requires large bandwidth channel with relatively small phase distortions. Due to long PN codes it requires long acquisition time. Near-to-far problem exists for DSSS systems.

Frequency-hopping (FH) systems

(+) Provide the greatest amount of spreading, can be arranged to avoid portions of the spectrum (I.e. those occupied by other systems or being the most affected by frequency selective fading) have a relatively short acquisition time.

(-) Requires a complex frequency synthesizer in order to generate the hops Always requires error correction. Only the average power is spread; the narrowband interference is either eliminated completely or not reduced at all.

3.5 APPLICATIONS OF SPREAD-SPECTRUM SYSTEMS TO COMMUNICATIONS

Modern spread spectrum is relatively well developed technology. In the past, SS used to be strictly used by the military. As this technology became declassified and available to the public, many commercial applications have been found for spread spectrum. After the May1985 FCC released the ISM bands for SS use, many commercial products have appeared ranging from low-speed fire safety devices to high speed wireless local area network (WLANs). Today, both voice and data communication industries are developing new products using spread spectrum technology.

The voice-oriented digital cellular and personal communication services (PCS) manufacturers are considering CDMA over traditional TDMA and FDMA. CDMA based on spread spectrum technology would increase wireless digital network’s capacity, provide more reliable service, and allow for soft hand-off of cellular connections (smooth transition from one cell to another). As a an example from the real world, a cellular provider Bell Mobility, which provides service in most Canadian areas, has abandoned TDMA technology IS-54 in favor of CDMA-based technology IS-95 (each was designed to complement analogue AMPS and to increase the capacity particularly in urban area).

3.5.1 IEEE 802.11

IEEE 8.2.11 is the first internationally recognized standard for Wireless Local Area Networks (WLAN), introducing the technology of mobile computing.

Network Topology

Ad-hoc Network

An Ad-hoc network or Independent Basic Service Set (IBSS) is a simple network where communications are established between two or more wireless nodes or stations (STAs) in a given coverage area without the use of an Access Point (AP) or server. The STAs recognize each other and communicate directly with each other on a peer-to-peer level.

Infrastructure Network

An Infrastructure network (or client/server network is a more flexible configuration in which each Basic Service Set (BSS) contains an Access Point (AP). The AP forms a bridge between the wireless and wired LAN. The STAs do not communicate on a peer-to-peer basis. Instead, all communication between STAs or between an STA and a wired network client go through the AP. APs are not mobile and form part of the wired network infrastructure. The Extended Service Set (ESS) consists of a series of BSSs (each containing an (AP) connected together by means of a Distribution System (DS). Although the DS could be any type of network (including a wireless network), it is almost invariably an Ethernet LAN. With an ESS, STAs can roam from one BSS to another and communicate with any mobile or fixed client in a manner which is completely transparent in the protocol stack above the MAC sub layer. The ESS enables coverage to extend well beyond the rage of the WLAN radio.

Physical Layer (Radio Technology)

Spreading and Modulation

IEEE 802.11 defines three variations of the Physical Layer: Infrared (IR) and two RF transmissions in the unlicensed 2.4 GHz ISM-band, requiring spread spectrum modulation: DSSS (Direct Spread Spectrum) and FHSS (Frequency Hopping Spread Spectrum). Only the RG transmission has significant presence in the market DSSS.

The DSSS physical layer uses an 11-bit Barker sequence to spread the data before it is transmitted. This sequence gives a processing gain of 10.4 dB. The 11 Meps base band stream is modulated into a carrier frequency (2.4 GHz ISM band, with 11 possible channels spaced with 5 MHz using:-

- DBPSK (Differential Binary Phase Shift Keying): data rate = 1 Mbps
- DAPSK (Differential Quaternary Phase Shift Keying: data rate = 2 Mbps

FHSS

In the FHSS physical layer the information is first modulated using:-

- 2-GFSK (2-level Gaussian Frequency Shift Keying): data rate = 1 Mbps
- 4-GFSK (4-level Gaussian Frequency Shift Keying): data rate = 2 Mbps

Both modulations result in a symbol rate of 1 Mbps.

The carrier frequency (2.4 GHz band, with 79 possible channels spaced with 1 MHz hops from channel to channel in a prearranged pseudo-random manner (hop pattern). There are 78 different predefined hop patterns (subdivided in 3 sets of 26 patterns). The FCC and ETS regulations required a minimum hop rate of 2.5 hops/s or a channel dwell time of less than 400 ms.

Spectrum

The spectrum of the transmitted signals determines the network packing.

DSSS

With a symbol rate of 11 Mbps the channel bandwidth of the main lobe is 22 MHz. There are 11 channels identified for DSSS systems, but there is a lot of overlap (only 5 MHz spacing). All IEEE 802.11 DSSS compliant products utilize the same PM code since there is not a set of codes available the DSSS network cannot employ CDMA. When multiple APs are located in close proximity, it is recommended to use frequency separations of at least 25 MHz. Therefore the 2.4 GHz ISM band will accommodate 3 non-overlapping channels. Only 3 networks can operate collocated.

FHSS

When the hop patterns are selected well, several APs can be located in close proximity with a fairly low probability of collision on a given channel. Up to 123 FHSS networks can be collocated before the interference is too high. This is based on the probability of collisions where two of the nets choose the same one of 79 channels at the same time. When the probability collisions gets too high, network throughput suffers, of course.

CHAPTER 4

4. MESSAGES AND HANDSETS IN CDMA

Features Discussed

- Message in CDMA
- CDMA System Handset
- The Rake Receiver
- Handoff Mechanism

4.1 MESSAGES IN CDMA

All the call processing in CDMA based system takes place by exchange of messages between the system and the mobile station on channels. CDMA has 4 basic types of channels for the forward and reverse links. These are;

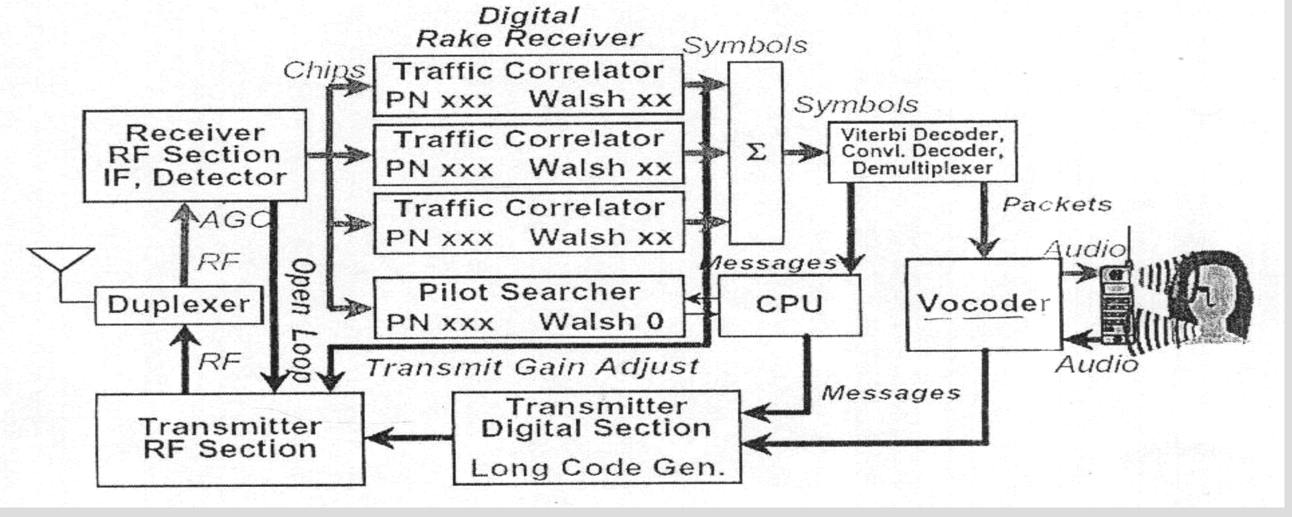
- Synchronization channel.
- Paging channels
- Access channel
- Traffic channels

The forward link contains the synch channel, the paging channel and the traffic channels where as the reverse link contains the access channel and the traffic channels.

The messages are always sent in a dim and burst format and the first byte of the message always contains the type of message being sent. Moreover these messages are with a sequence number, which helps to facilitate the order of the message. Certain messages also require acknowledgements from the receiving side. In case an acknowledgement is not received there are retransmissions. Messages are fundamental to CDMA and they are captured and displayed by special data processing tools, which can be used to study these messages.

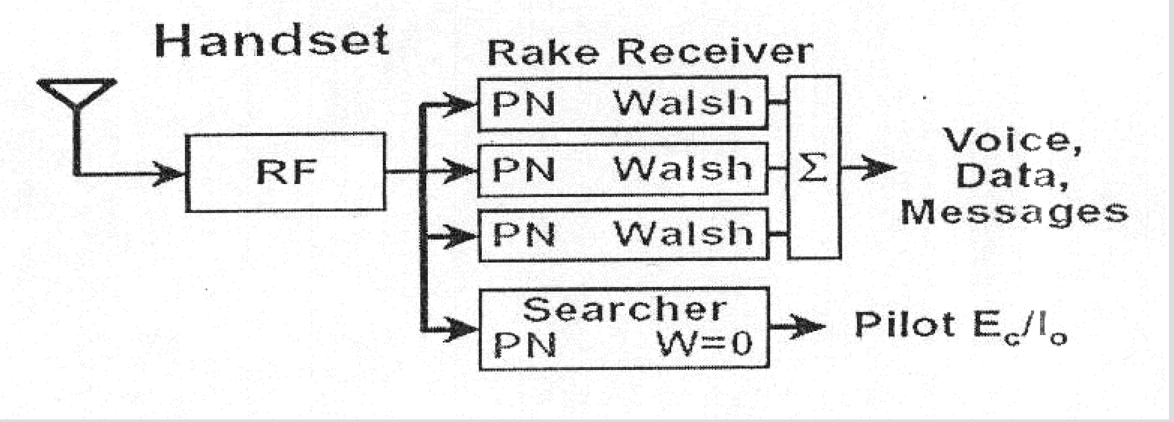
4.2 CDMA SYSTEM HANDSET

The block diagram depicts essential components of the hand set used in CDMA system. These components are labeled in diagram.



4.3 THE RAKE RECEIVER

The rake receiver consists of three fingers; each can independently receive a particular PN and particular Walsh code. These rake figure can be targeted to received PN from different PTS and delayed multipath reflections. The figure also shows a pilot searcher rake finger, which continually monitors channels pilots.

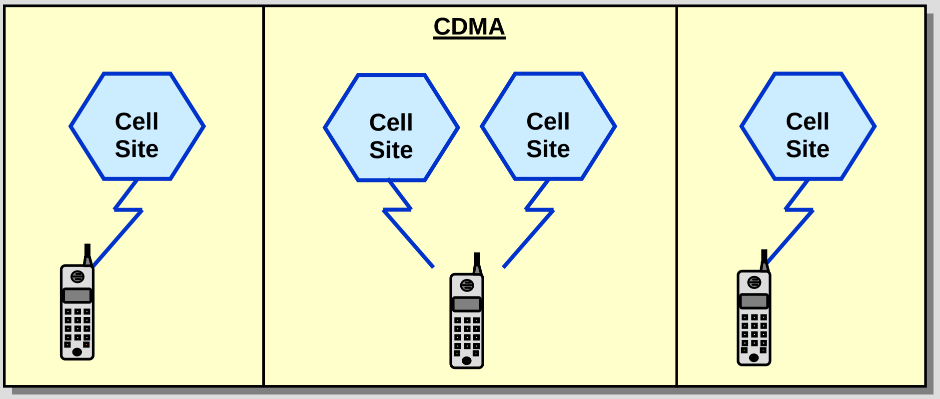


4.4 HANDOFF MECHANISM

4.4.1 Handoffs

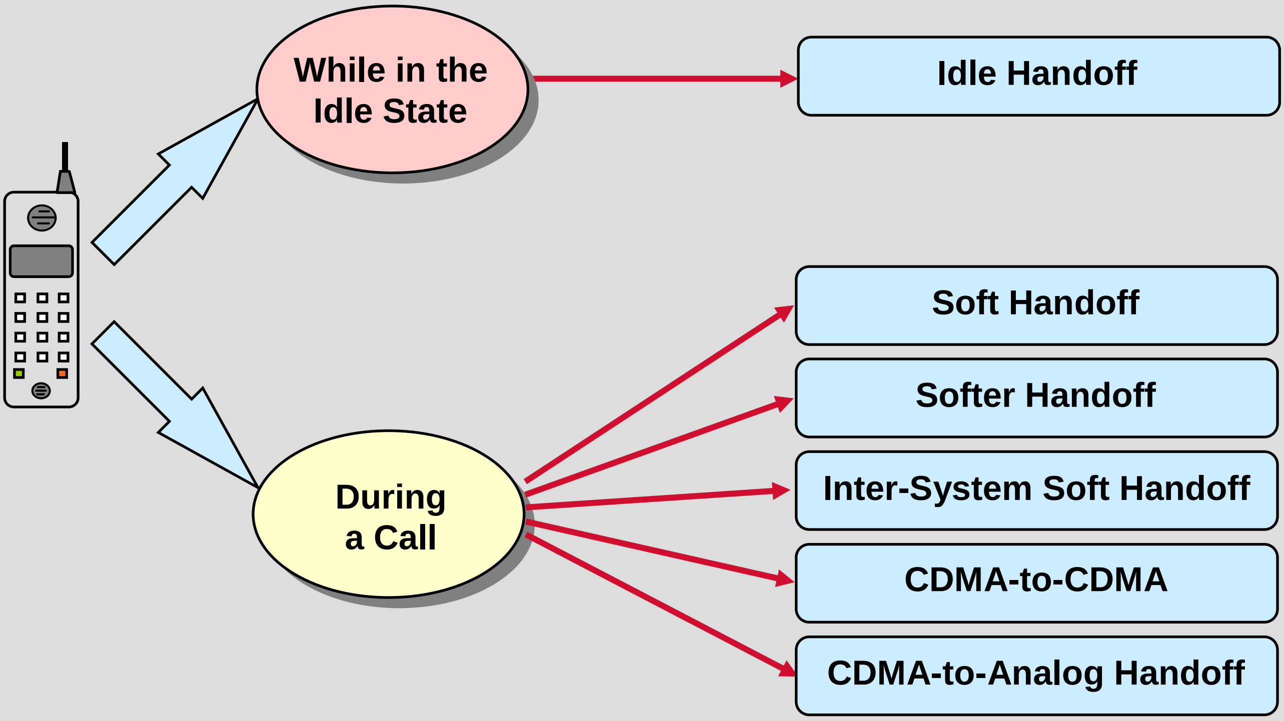
- Handoff is the process by which a mobile
  station maintains communications with the Mobile Telephone Switching center (MSC), when traveling from the coverage area of one base station to that of another.
- Handoffs keep the call established during the following conditions:
- Subscriber crosses the boundaries of a cell.
  Subscriber experiences noise or other interference above a specified threshold.
  A base station component experiences an out-of-service condition during a call.

CDMA Handoffs



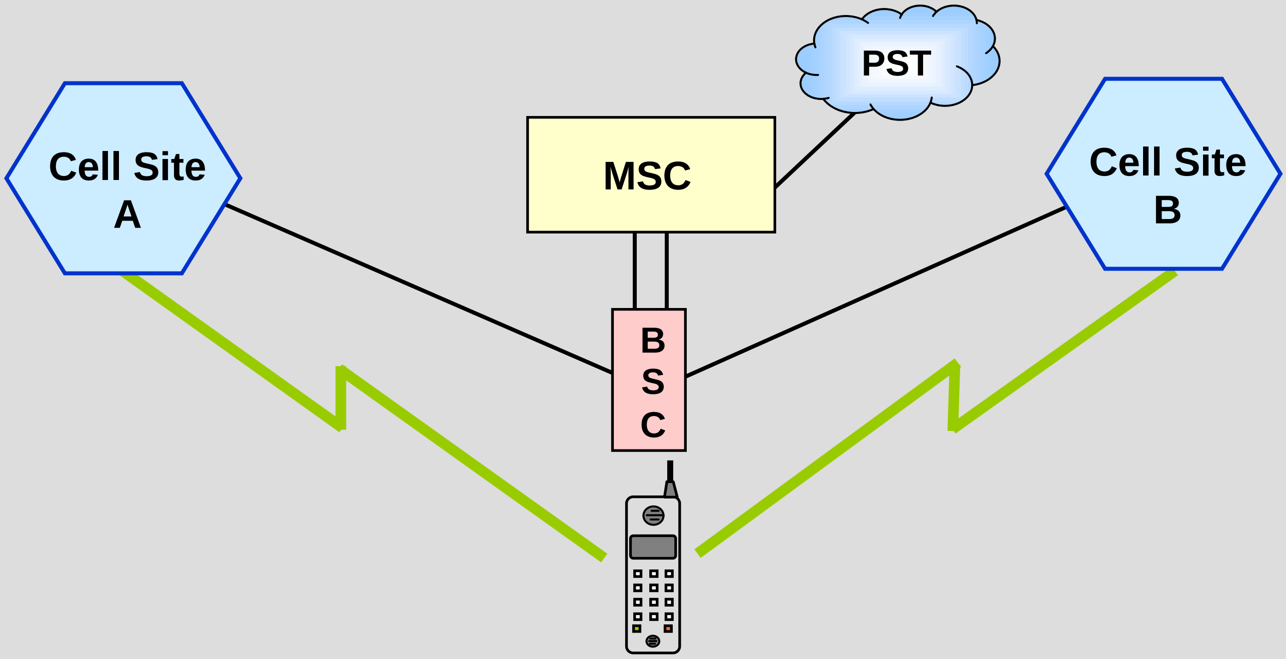
- CDMA Handoffs
  - Make-before-break
  - Directed by the mobile not the base station
  - Undetectable by user
  - Improves call quality
- Handoffs consist of the following phases:
  - Initiation (trigger), Target Selection, and Completion (execution)

4.4.2 CDMA Handoffs (cont.)



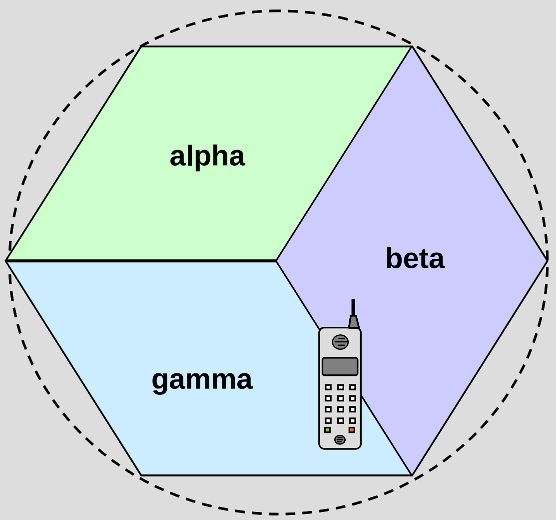
4.4.3 Soft Handoff

- Soft Handoff: the mobile station starts communications with a target base station without interrupting communications with the current serving base station.
- Can involve up to three cells simultaneously and use all signals
  - Mobile station combines the frames from each cell

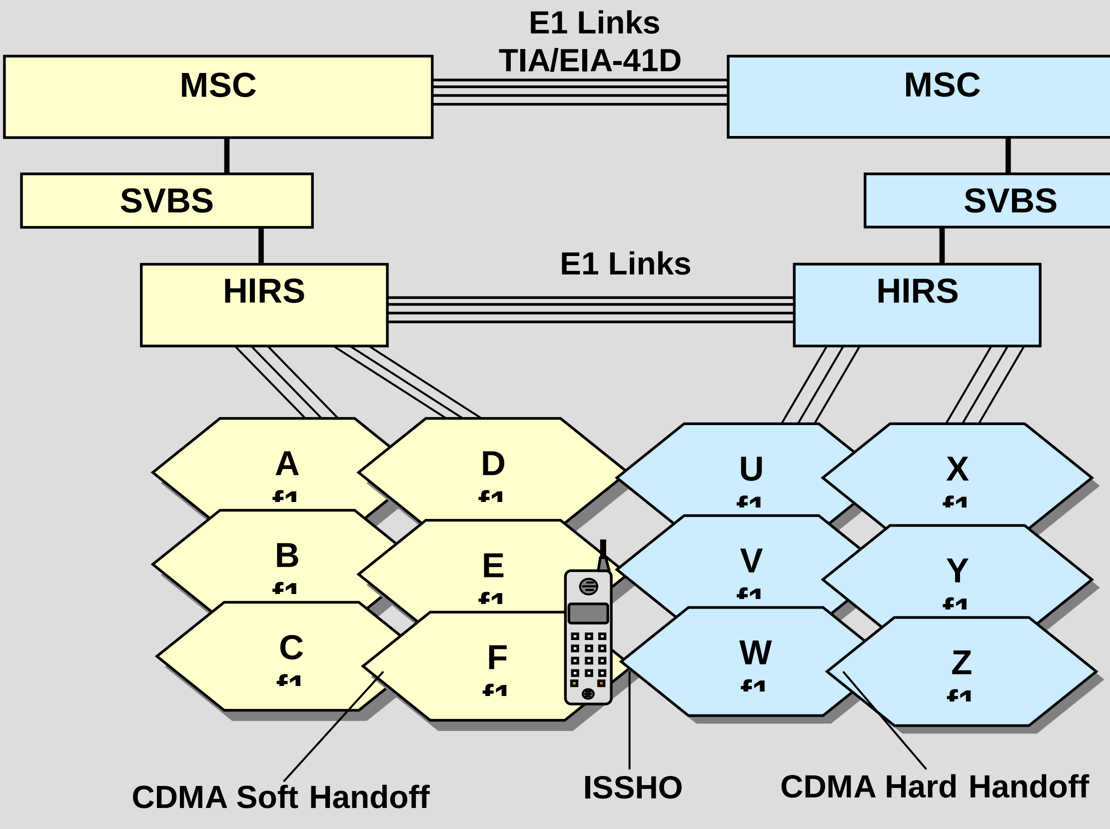


4.4.4 Softer Handoff

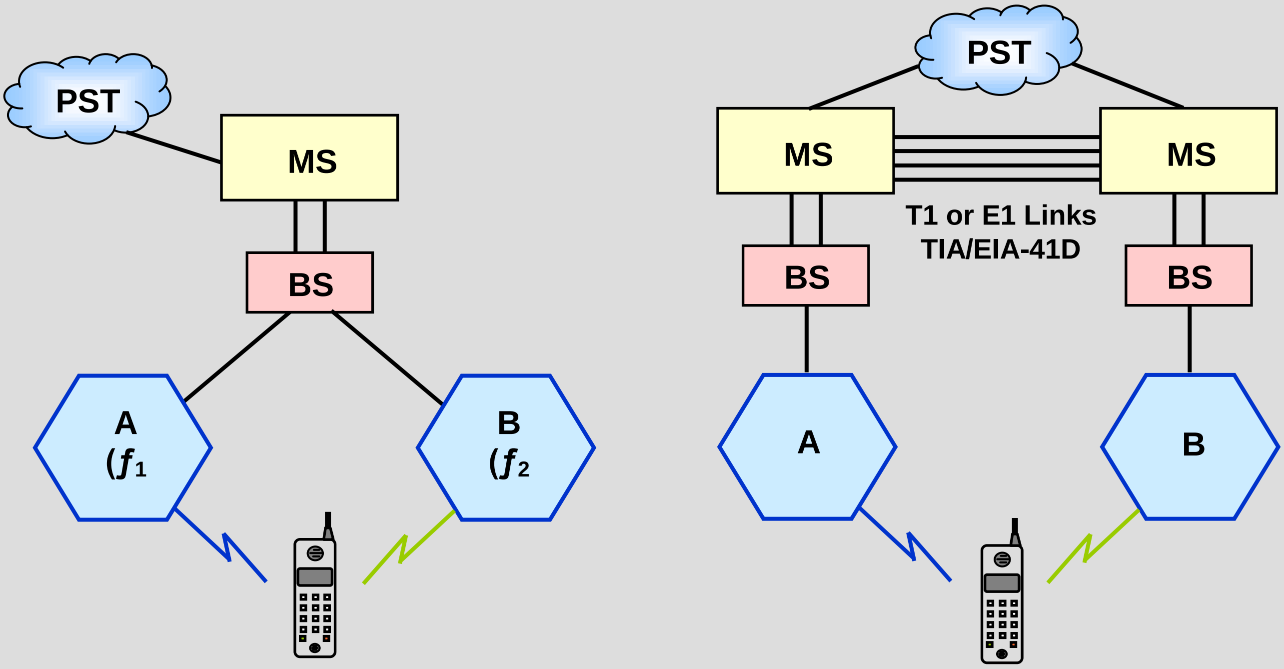
- Handoff is between sectors of the same cell
- Communications are maintained across both sectors until the mobile station transition has completed
- May happen frequently
- MSC is aware but does not participate
- All activities are managed by the cell site
- Signals received at both sectors can be combined for improved quality



4.4.5 Inter-System Soft Handoffs (ISSHO)



4.4.6 CDMA--to-CDMA Hard Handoff



- Between cells operating on different frequencies
- Between cells that could be on the same frequency, but which are subordinated to different MSC

4.4.7 Idle Mode Handoff

In idle mode soft handoff cannot take place since the mobile set is listening to the paging channel and each sector as a different paging channel information stream and hence they are not synchronized with each other. So we cannot combine the signals. The mobile station pilot searcher is constantly searching for pilots. If a better pilot is found the set finishes the current super frame of the active pilot and then switches to the new pilot and its paging channel. Hence the handoff is completely unaware of the handoff and it is totally driven by the handset. If registration is required on new pilot the set will re-register itself on new sector. The pilots to be searched are gathered from the neighbor list message provided by the system.

CHAPTER 5

5. WLL NETWORKING

Features Discussed

- Base-Station Sub-System
- Base-Station Controller (BSC)
- Base Transceiver Station BTS
- BSS System Networking Modes
- BSS Hardware Architecture
- MSC/VLR System Overview
- Voice Message Notification
- CSM: Central Switching Module
- SNS: Switching Network Module

The overall networking in WLL networking is shown below:-

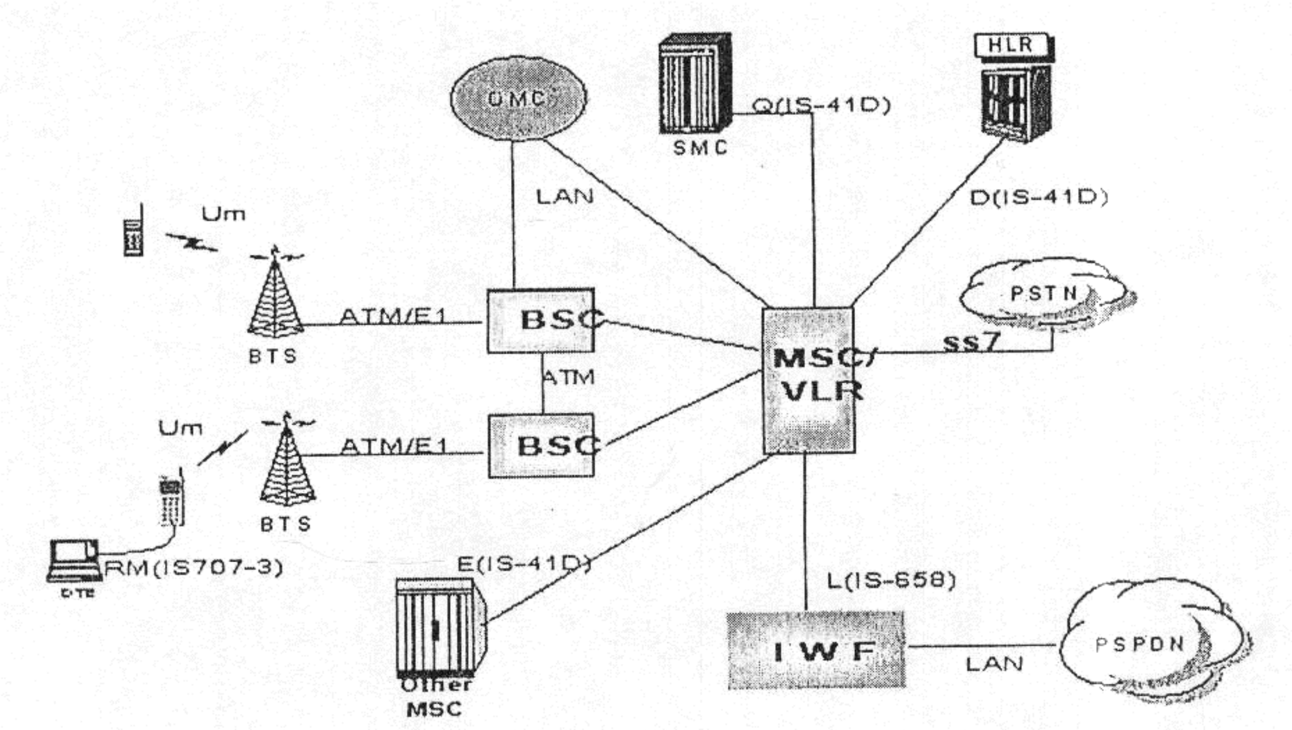
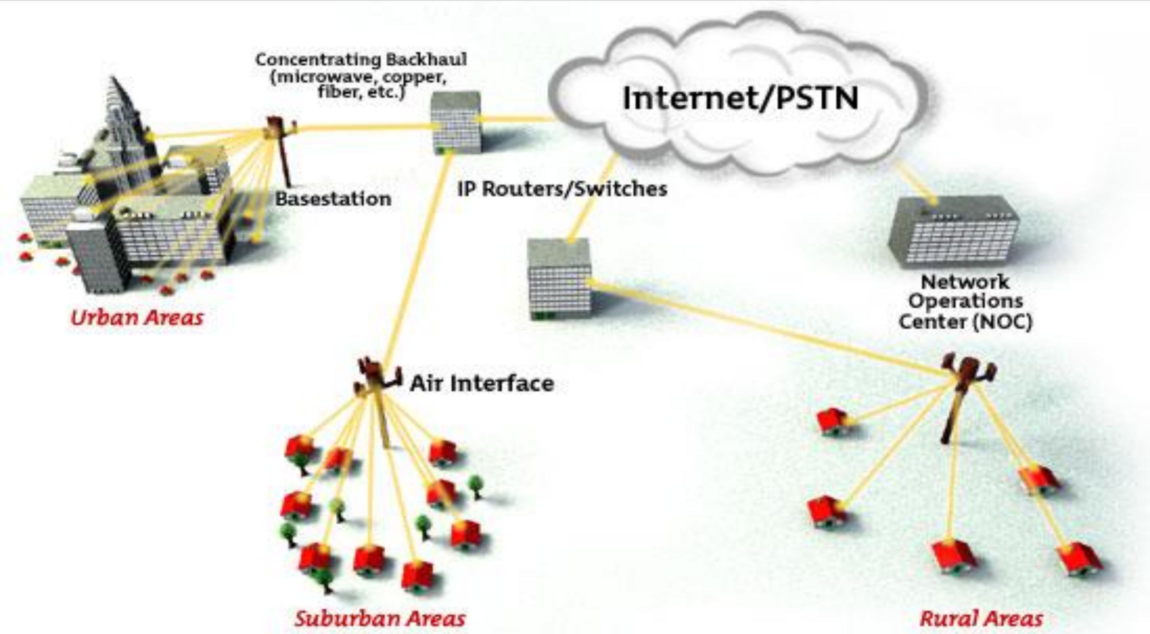


Fig 7.1



Typical WLL system **Source: Nortel Networks**

Fig 7.2

5.1 TYPES OF STATION

Net working mainly consists of two main systems;

1. **Base-Station System**
2. **MSC/VLR System**

5.2 BASE-STATION SUBSYSTEM

BSS system is the kernel part of the CDMA Cellular Mobile Communication System Base Station System. It is connected with mobile stations through air interfaces on one hand and with mobile switches through A-interfaces on the other.

The structure of the BSS base station is illustrated in Figure.

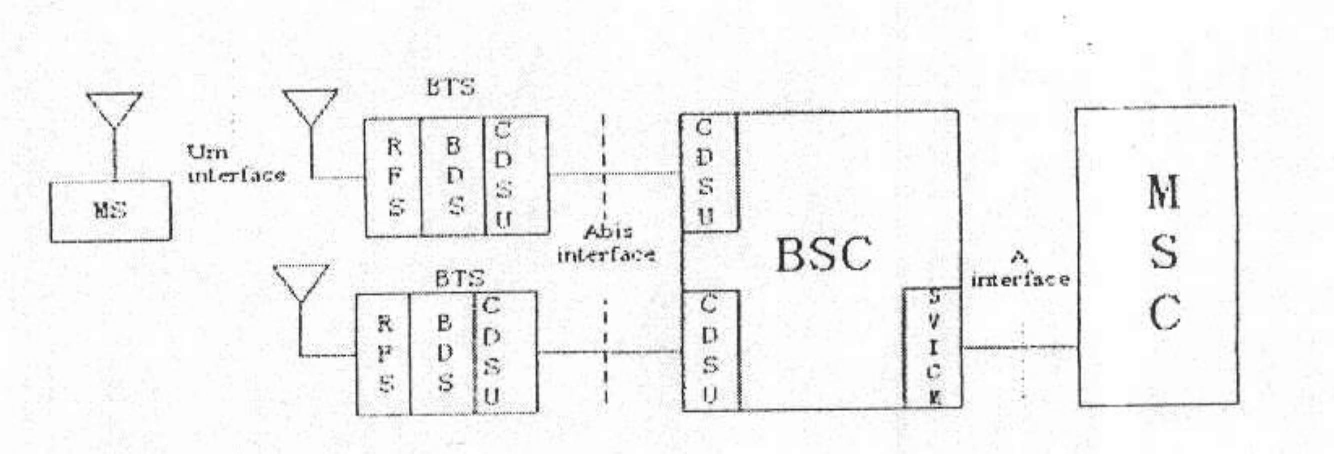


Figure Structure of BSS

BSS system is composted of two parts:-

1. Base station controller (BSC)
2. Base transceiver (BTS).

5.2.1 Base Station Controller (BSC)

BSC is the control part of the Base Station System (BSS). BSC is connected with the BTS through a CDSU and the other end is connected with the MSC through a SVICM. BSC acts a wireless network management and wireless resources management. It has following main functions:-

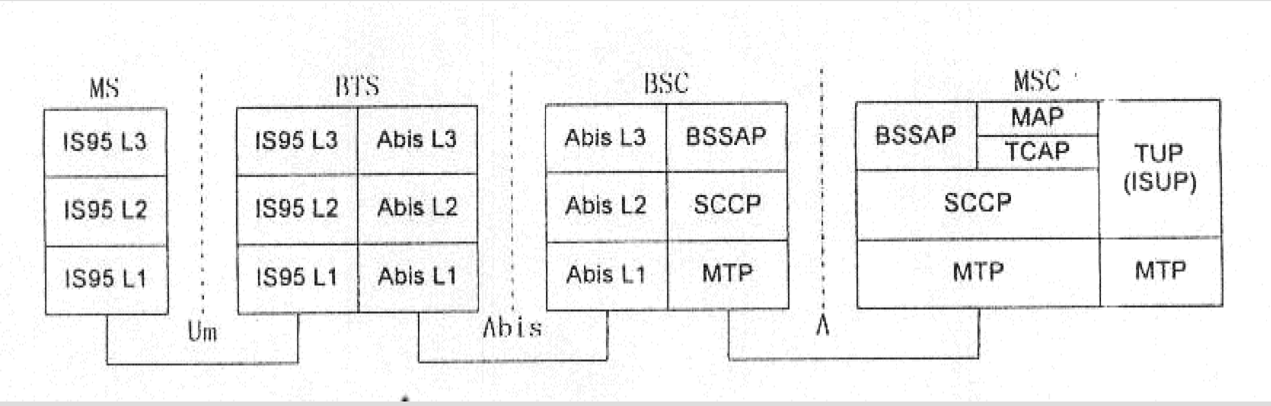
1. BSS Maintenance and Management
2. Call Processing and Control
3. MS Handover
4. Voice Coding

5.2.2 Base Transceiver System (BTS)

Base transceiver system (BTS) is the wireless part of BSS. BTS realizes the wireless transmission and related control functions.

5.2.3 Various Interface Protocols of BSS

Protocol stack structure of CDMA mobile communication system is illustrated in Figure.



The BSS system has 3 types of interfaces:-

1. Um interfaced with the MS
2. Abis interface between the BSC and BTS
3. A-interface with the MSC

5.2.4 BSS System Networking Modes

BSS usually appears in the following basic network modes, star networking, ring networking, chain networking and mixed networking:-

Star Net Working

The star networking mode is BSS is shown in Figure.

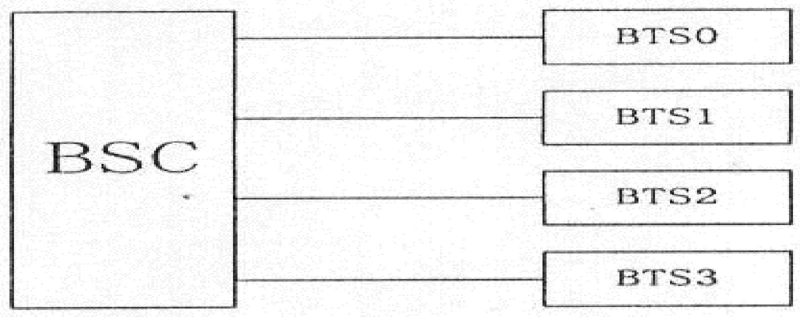
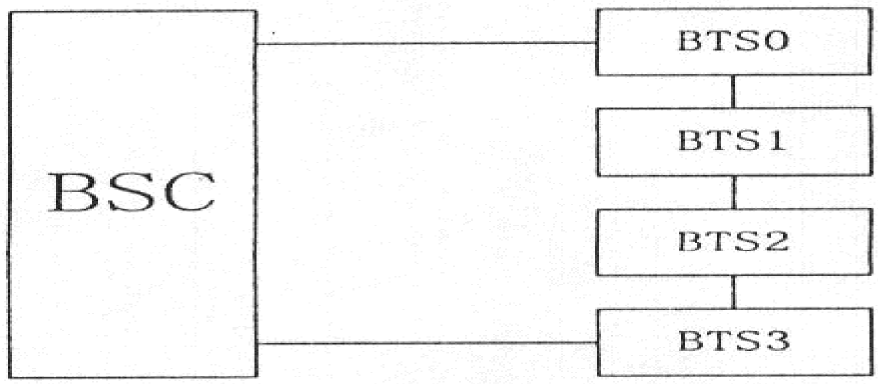


Fig. Schematic Diagram of Star Networking

In star networking, n EI PCM links are led into each SITE directly by the BSC. The BTS device on each station is an end device. The networking mode is simple and the maintenance and engineering are both convenient, Signals do not go through many links and therefore the line reliability if very high. This kind of networking mode is usually used in populous urban areas.

Ring Networking

The ring networking mode of BSS is shown in Figure.

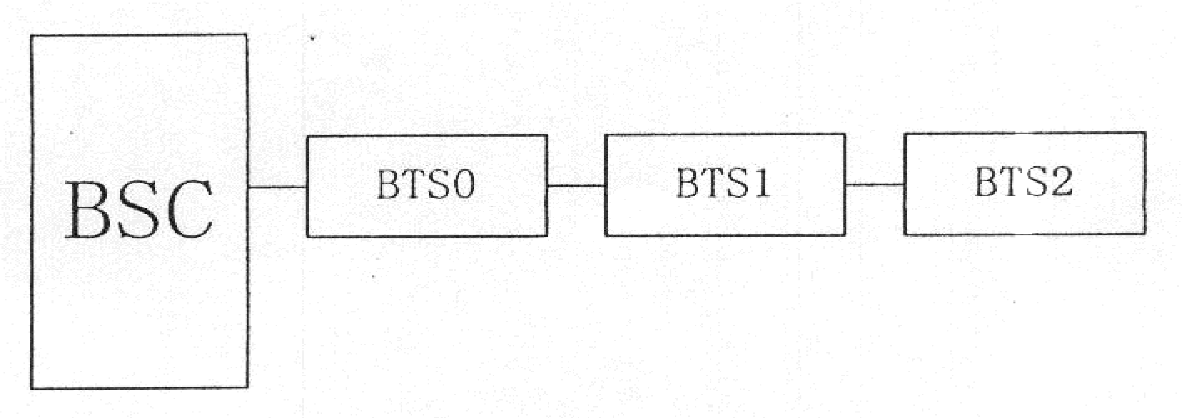


Schematic Diagram of Ring Networking

In ring networking, there are two sets of mutual-backup links. Each node in the ring has two upper-level nodes, which enhances the links' reliability. If one Site is damaged or if one link fails, the subordinate nods can select the other link as the active link.

Chain Networking

The chain networking mode of BSS is shown in Figure.



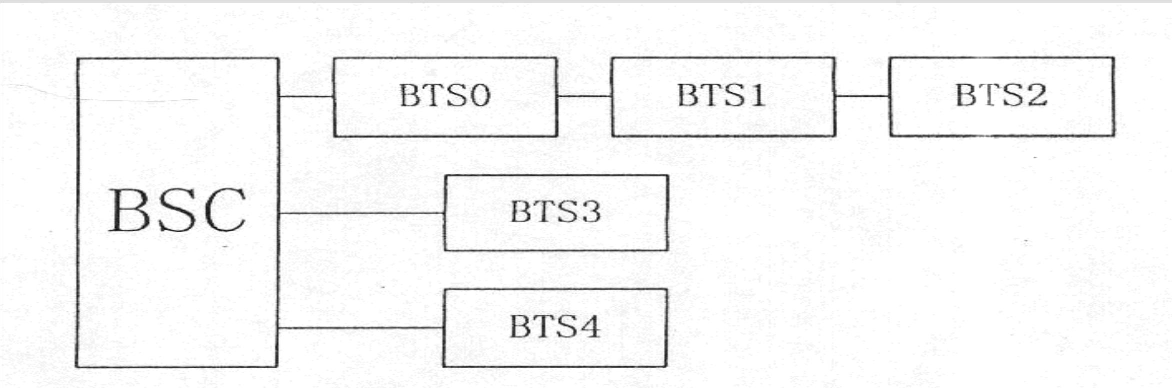
Schematic Diagram of Ring Networking

Chain networking is also suitable for the one-station-multiple-BTS situation. Signals go through quite a number of links and the line reliability is relatively poor. Able to save a large numbers of transmission devices, this networking mode is suitable for areas of that appear in the band shape and have small population.

During actual networking engineering, since the stations are scattered around,
different transmission devices are usually used between BSC and BTS as the intermediate connection. Common transmission modes include microwave S transmissions, optical cable transmission, HDSL cable transmission and coaxial cable transmission etc.

Star-Chain Combined Networking

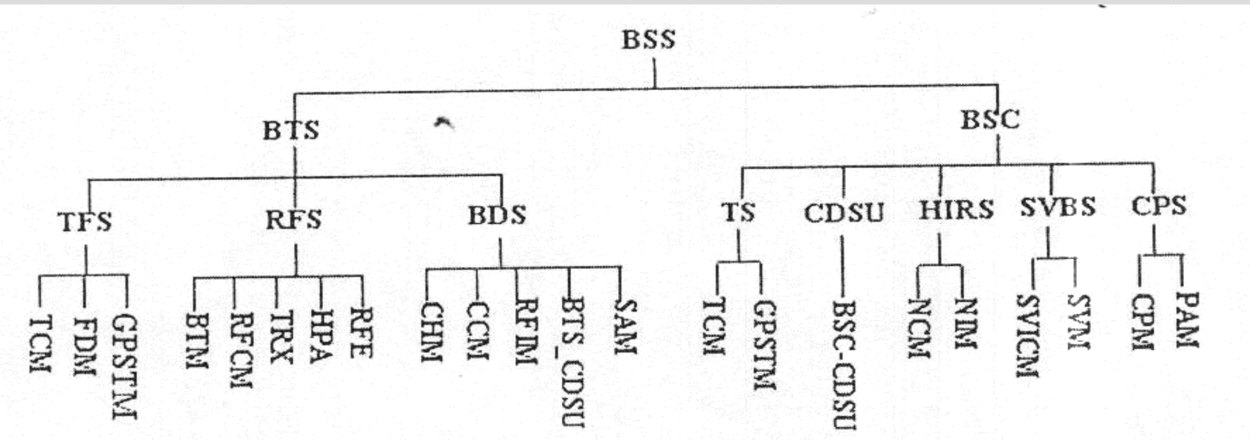
The star-chain networking mode is illustrated in Figure.



5.2.5 BSS Hardware Architecture

Overview

The logic structure of the BSS system is shown in Figure.



Logic Structure Diagram of BSS

The actual network structure and overall framework of CDMA BSS system are illustrated.

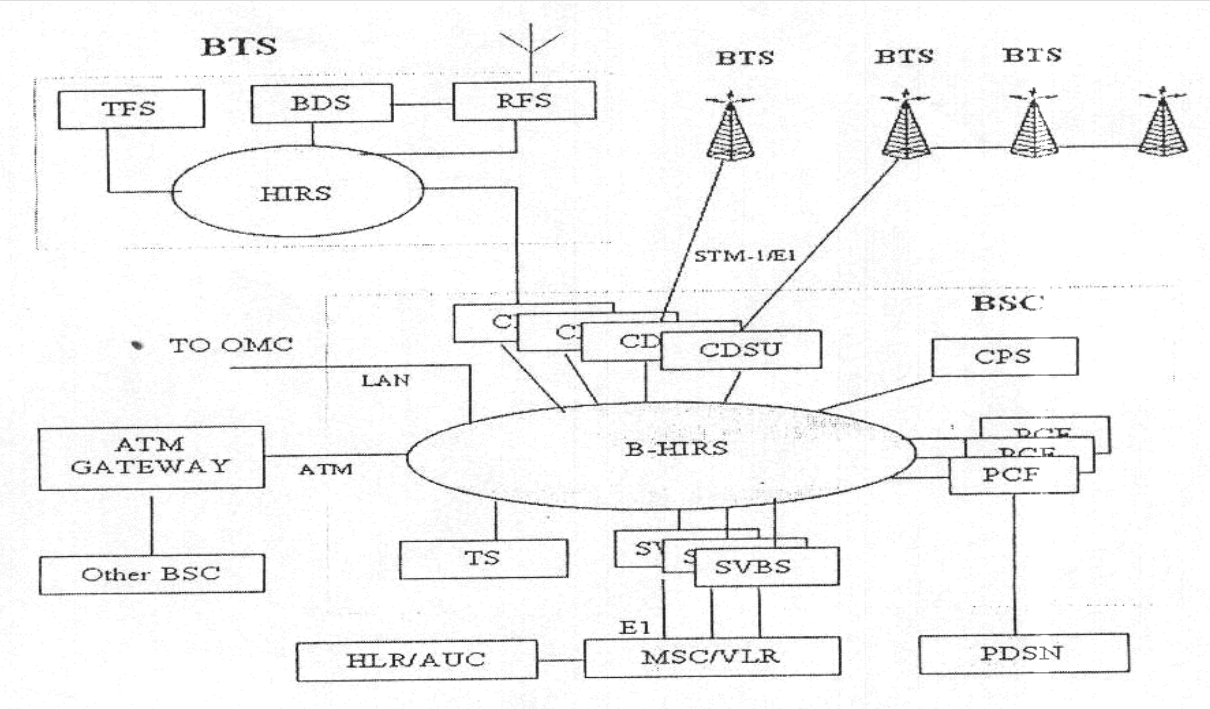


Fig. Structure of ZXC10-BSS

The network structure of CDMA BSS system is divided into two levels:-

- B-HIRS
- S-HIRS

B-HIRS

The first level is the BSC's HIRS subsystem, called "B-HIRS". It is the packet data switching Centrum of the whole system. The system's signaling protocol processing centre call processing subsystem (CPM) is directly connected to the 'bit HIRS', the system's vice coding/decoding device – selector/vocoder and subsystem (SVBS) is also directly connected to the "bit HIRS", the system's operation and maintenance centre – base station manager (BSM) is connected to the NCM of the "bi HIRS" through an Ethernet port and the modulating/demodulating devices of various BTSs - base band digital subsystem (BDS) are connected to the BSC – CDSU of the "big HIRS" through non-channelized EIs Main function of the B-HIRS is to provide packet switching service for all the modules or subsystems that connect to it. Any equipment that needs to communicate with other sub-systems can realize communication with each other through it.

S-HIRS

The second level is the packet data switching network with a relatively low speed formed in the SNBS or BDS subsystem, called "S HIRS". Its main function is to provide packet data switching service for various modules in the SVBS or BDS subsystems. The major difference between the S-HIRS and B-HIRS is the data switching rate. B-HIRS has much higher data switching rate than S-HIRS.

PSMB	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NCM	NCM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	NIM	PSMB

NCM: Network Control Module

NIM: Network Interface Module

PSMB : Power Supply Module

5.2.6 BSC Hardware Architecture

BSC: Base Station Controller, includes the following parts:-

HIRS: High-Speed Interconnect Router Subsystem

The system structure of whole HIRS adopts shared memory structure (bus-type) based on fast packet switching network, which forms the backbone of HIRS network switching platform. It consists of following two main modules.

NCM: Network Control Module

NCM is the core module in HIRS shelf

- When NCM is in slot 11, it must connect with port 6 of NIM in slot 9 via the internal serial bus on backplane.
- When NCM is in slot 12, it must connect with port 6 of NIM in slot 14 via the internal serial bus on backplane.
- 2 NCM working mode: active and standby

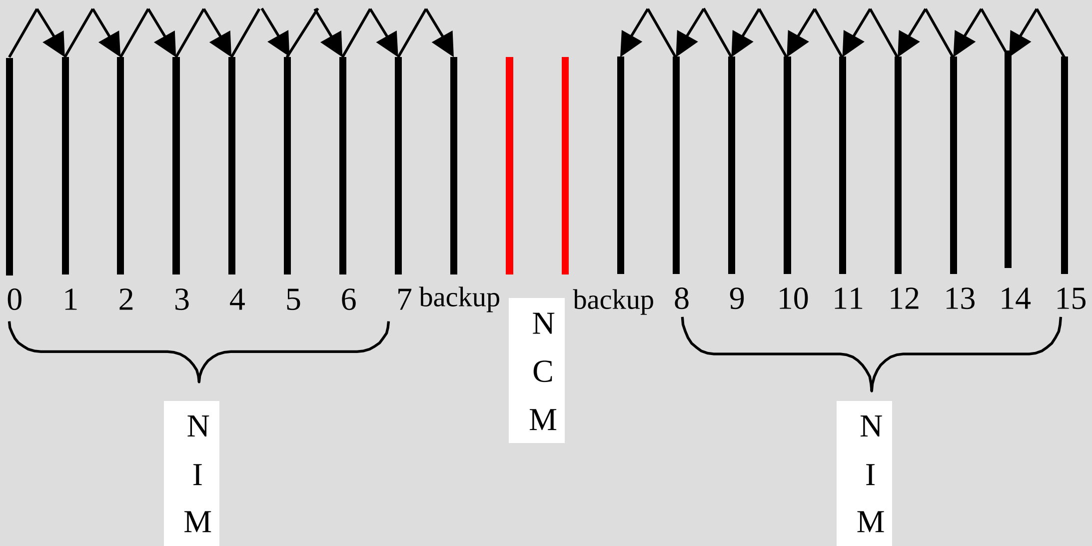
Major functions of NCM:

- Gateway function: data receiving of CO bus and distribution of DIS bus,routing of data frame inside/outside of the local shelf
- Distribution of software of respective modules and configuration information;
- Fault detection, isolation, report and recovery in HIRS network;
- GPS clock distribution;
- Serving as the foreground PC of BSM to communicate with the background through 10/100Mbps Ethernet

NIM: Network Interface Module

It is interfaced unit which is used to access various port devices in CDMA BSS system to the HIRS network. In each HIRS frame structure there are 18 NIM out of which 16 are active and 2 are for standby

NIM daisy chain NIM: 8 working + 1 standby and changeover



SVBS: Selector/Vocoder Bank Subsystem

SVBS sub-system consists of one SVICM and 15 SVMs. Its general frame diagram is as follows:

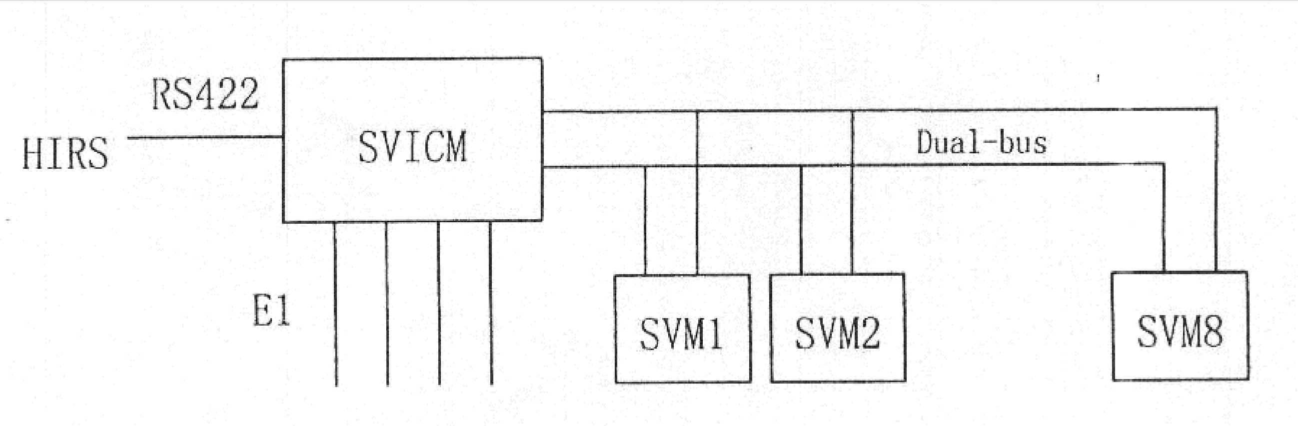


Fig. SVBS Sub-system overall structure diagram

SVBS has following main functions:-

1. Path selection function
2. Transcoding function
3. Forward echo restrain function
4. Decision and soft handoff execution
5. Power control
6. Signaling handle functions.

SVBS can simultaneously provide 15*8=120 selector/vocoder and 4 EI channels connected to MSC, which is used to transmit service data of an interface. SVBS contains following two main functional units:-

P	S	S	S	S	S	S	S	S	S			S	S	S	S	S	S	S	S	S	P
S	V	V	V	V	V	V	V	V	V			V	V	V	V	V	V	V	V	V	S
M	M	M	M	M	M	M	M	M	I			I	M	M	M	M	M	M	M	M	M
B									C			C									B
									M			M									

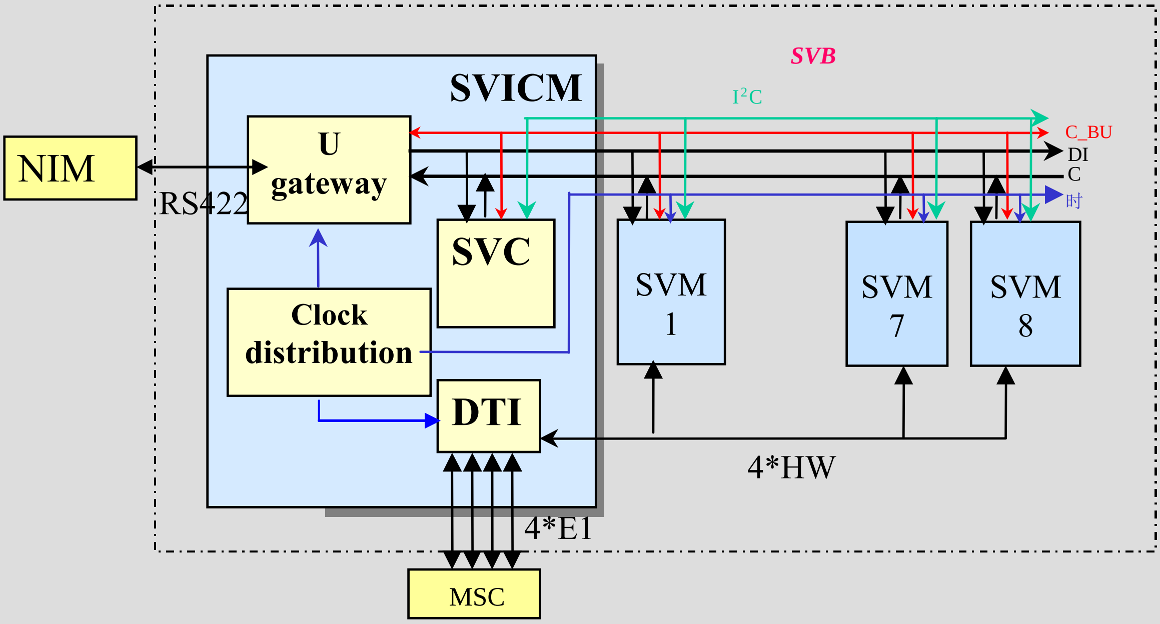
SVICM: Selector Vocoder Interface Control Module

SVM: Selector Vocoder Module

PSMB：Power Supply Module

Vocoder interface control module (SVICM)

SVICM is the core control part of SVBS, which is connected with other parts of BSS via SVICM. In addition, it's also the physical channel between BSS and MSC.



SVICM Functions

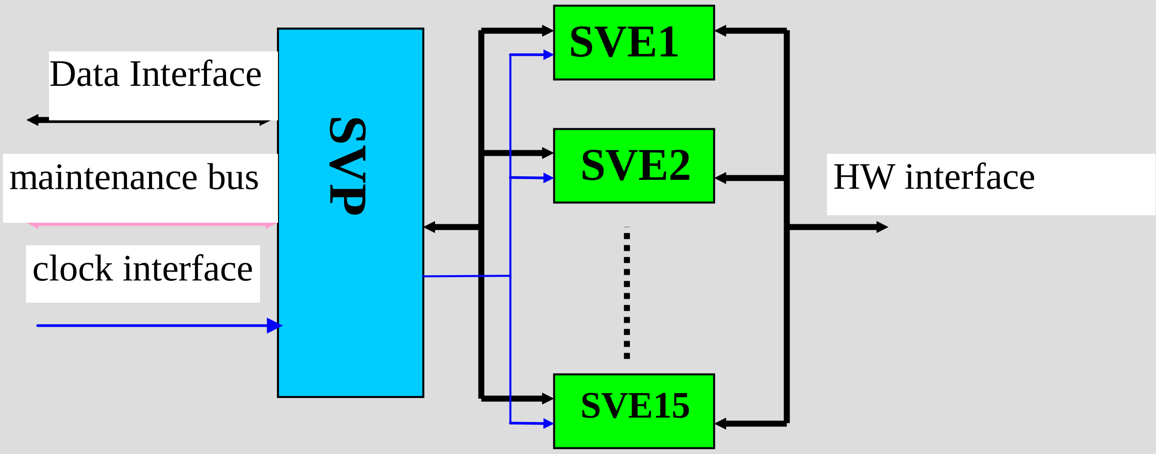
- S-HIRS:Communicate with HIRS Network
  - ✓ Distribute forward traffic and signaling （SVM→SVICM → NIM）
  - ✓ Distribute reverse traffic and signaling (SVM←SVICM ← NIM）
  - ✓ Distribute signaling interior SVBS （SVM↔SVICM ）

- Receive and Distribute Clock and TOD message
- Manage and control SVM
- Signaling handling
- Code type conversion between MSC and BSS via DTI

Vocoder/selector module (SVM)

SVM is the base of SVMB and it contains 15 vocoders. SVBS is responsible for the following main functions;

1. Conversion between 64 kbs PCM code and QCELP code.
2. Supports the voice channel in soft handoff.
3. Participates in reverse outer-loop power control.



CPS: Call Processing Subsystem

CPS subsystem is a joint of BSS system's resource management and call signaling protocol processing. CPS contains only one basic module – call processing module (CPM), which is connected with a port of NIM module in HIRS. It is composed of following modules.

CPM: Call Processing Module

CPM is responsible for calling management and its major function is ABIS interface's signaling processing for the whole CDMA system, radio resource management. There are two CPM modules one in active and the other is in standby mode.

PAM: Power Alarm Module

It is located in BSC side CDSU frame, it has function to monitor the running status of power supply modules in BSC side and equipment room environment signals such as temperature, smokes and send result to NCM.

BTS Hardware Architecture

BTS: Base Station Transceiver, includes the following components:-

1. **BDS:** Base band Digital Subsystem
2. **TFS:** Timing Frequency Subsystem
3. **RFS:** RF Subsystem

BDS: Base band Digital Subsystem

The main functions of DBS are to implement the modulation and demodulation of base band signals and the interfacing with the RF part and the Abis interfacing with the BSC. One BDS is composed of up to 12 channel processing modules (CHMs), 2 communication control modules (CCM), 2 RF interface modules (RFIMs) and 1 BTS – CDSU module.

The BDS system can provide the modulation and demodulation of up to 12x16=192 wireless channels(including overhead channels, soft handover service channels and subscriber service channels), and supports up to 2-carrier 3-sector configuration. The BDS system can provide one non-channelized E1 interface (Abis interface) with the data rate of 2 Mb/s or two non-channelized E1 interfaces of the same data rate working in load sharing mode. The BDS system can also provide interfacing for up to six TRX's. The schematic diagram of the BDS frame is shown in Figure.

POWA	CHM	CHM	CHM	RFIM	CHM	CHM	CHM	SAM	CCM	CCM	CDSU	CHM	CHM	CHM	RFIM	CHM	CHM	CHM	POWA

Table, Schematic Diagram of BDS Frame

DBS is further divided into following main modules;

CHM: *Channel Processing Module*

CHM is the main part of CDMA channel, responsible for modulation and demodulation of various CDMA channels and realizes the partial function of power control.

CCM: *Communication Control Module*

In CDMA base station system, the main function of CCM is to realize centralized control for data signaling route, signaling handling, resource management and maintenance operation of whole BDS subsystem.

RFIM: *RF Interface Module*

Controlled by the communication control module (CCM) is the connection point between the digital subsystem and the RF subsystem. The major functions of this module are as follows:-

- Transmission and processing of transmission and reception base band data.
- Transmission and processing of non-emitted and non-received baseband data.

SAM: *Site Alarm Module*

SAM is located in the BDS frame of BTS side. Its function is to supervise the status of power supply module and fan as well as the signals of door opening, flooding, temperature/humidity, smog and other environment signals and report the results to the CCM.

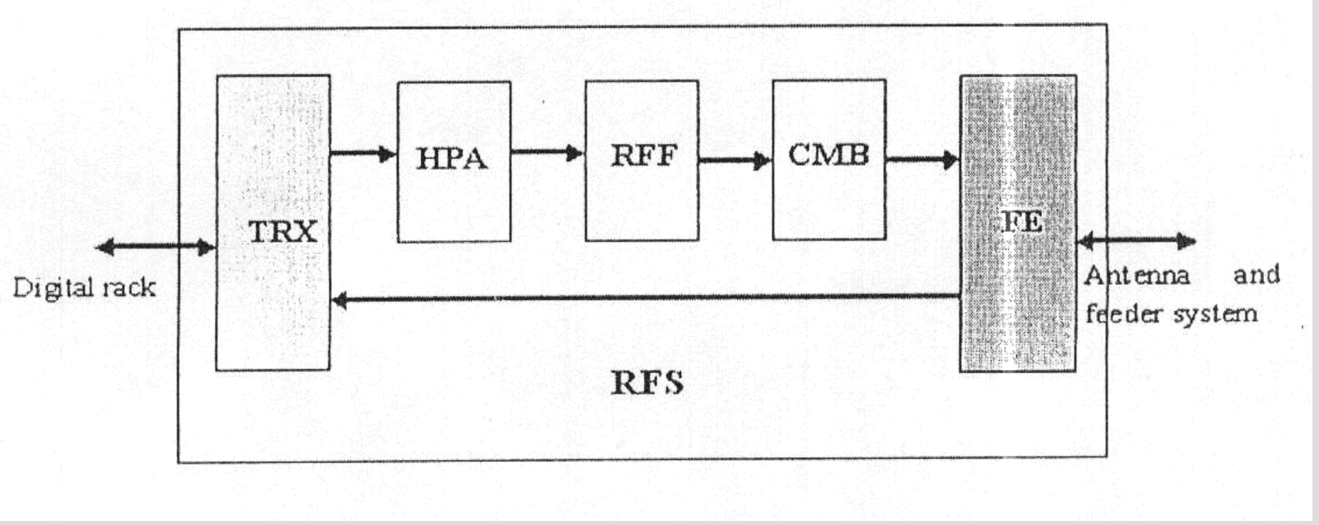
BTS – CDSU: *BTS-Side CDSU Module*

In CDMA system the interface between BTS and BSC is Abis interface. This interface links BTS with BSC through and E1 trunk line in daisy chain mode. BTS side Channel data service unit is basically a board module that implements the Abis interface functions.

RFS: RF Subsystem

RFS subsystem includes the following main things and is shown in the schematic diagram below:-

1. REF
2. HPA
3. CMB
4. FE



Radio Frequency Front-end (RFE)

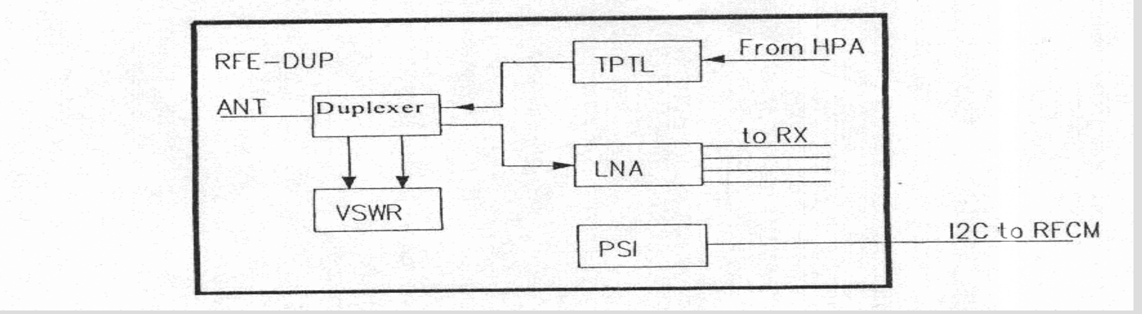
It is interface between internal system of the RFS in the BTS and external antenna of the BTS. Each RFE frame consists of six RFE modules. RFE module has following main functions:-

1. Filtering and low noise amplifying for weak signal received from antenna.
2. Power distributing of received signal after low noise amplification.
3. Filtering of forward transmitting power signal
4. Supervising low noise amplifier’s status.
5. Supervising power and providing relative measurement result.

In BTS side we have two types of RFE modules;

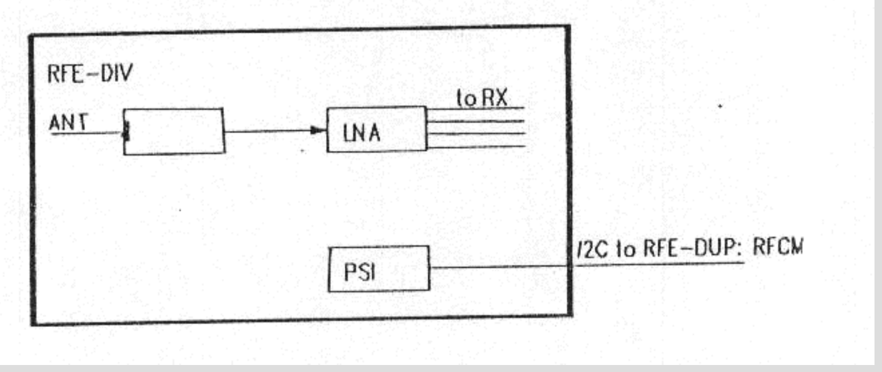
1. RFE DUP

It is for both transmission and reception as shown in the figure.



2. RFE DIV

It is for only reception of the signals as shown in the figure.



High Power Amplifier (HPA)

HP performs power amplification of the TRX forward transmission signal in order to achieve desired power level of the transmitted signals in the cell. A HPA frame consists of six HPA modules.

Radio Frequency Transceiver (TRX)

It is a link connecting RF and base band signal and it correspond to one sector of one carrier.

Backward Channel Operation

In on a backward channel, The TRX receives the signals of a sector and performs respectively down conversion and intermediate frequency filtration, I/Q demodulation, to convert the received RF modulated signal to base band I and Q signals.

Forward Channel Operation

For forward channels, the TRX receives the baseband I and Q signals for I/Q modulation, which go through intermediate frequency filtration and up converted to RF modulated signals.

RFCM: Radio Frequency Control Module

RFCM is centralized intelligent control device in RFS and perform monitoring of various major function units in RFS such as;

- Multiplexing/demultiplexing o9fboth forward and backward baseband data signals.
- D/A and A/D conversion.
- Status monitoring of various functional units as well as special function controls of the RFS.

BTM Module

BTM (Base station testing module) is used for BTS testing.

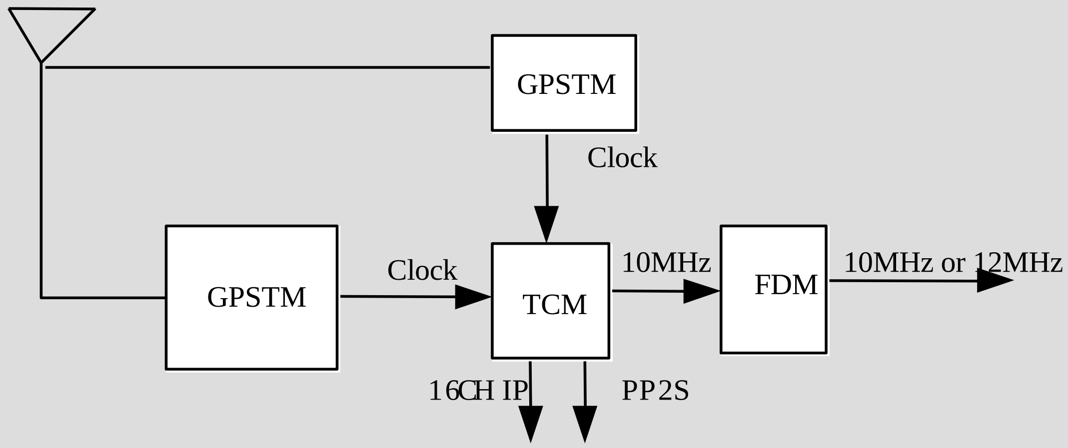
TFS: Timing Frequency Subsystem

The TFS provides GPS synchronized timing signals for BTS. The TFS includes three modules.

1. GPSTM
2. TCM
3. FDM

GPSTM

The **GPSTM** is used for the reception of timing signals from the GPS satellite and generation of basic timing signals.



TCM: *Timing* ***Control Module***

The TCM is used for phase locking generation of 16 chip clock etc.

FDM: *Frequency Distribution Module*

The FDM is used for frequency distribution.

5.3 MSC/VLR SYSTEM OVERVIEW

MSC/VLR system is mainly composed of the CSM (SNM+MSM) module, MPM module and the operation and maintenance system. Inter-module communication is implemented by means of optical fiber and interconnectivity with other system like BSC, PSTN, ISDN, PSPDN and PLMN by means of No 7 signaling network.

The overall structure of the system is shown in Figure below and it consists of following main modules:-

1. **CSM:** Central Switching Module.
2. **SNM:** Switching Network Module.
3. **MSM:** Message Switching Module.
4. **MPM:** MSC/VLR/SSP Processing Module.
5. **OMM:** Operation and maintenance module.

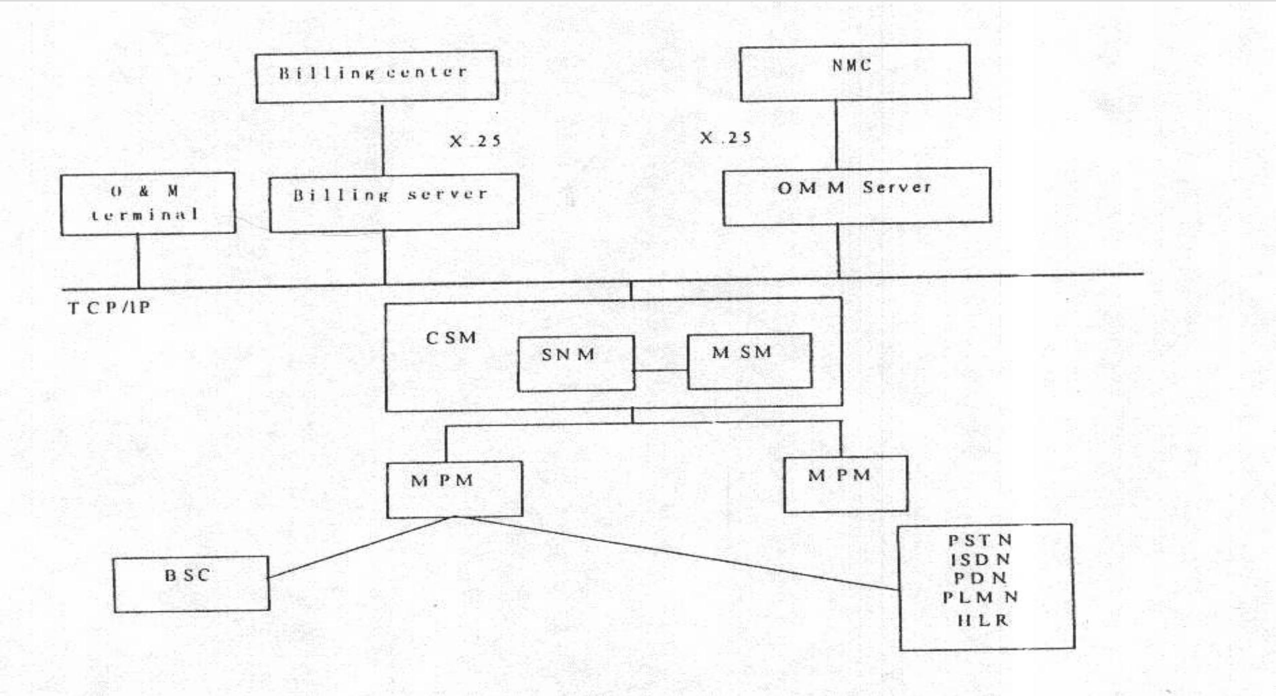


Fig. Schematic diagram of MSC/VLR System Structure

5.3.1 CSM: Central Switching Module

The CSM module is used to control inter-module communication and message interaction in multi-module configuration and it can be configured or omitted according to the actual requirement.

5.3.2 SNM: Switching Network Module

The switching network (SNM) is the kernel module of a multi-module office system. It mainly implements the voice channel switching among various modules in the multi-module system and sends the communication time lots from the multi-module to the MSM via semi-permanent connection.

5.3.3 MSM: Message Switching Module

The message switching module (MSM) mainly implements the message witching among various modules. The MPM is connected to the SNM via optical fibers and their communication slots are connected through the SNM's semi-permanent connection to the MSM.

5.3.4 MPM: MSC/VLR Processing Module

It can implement the voice channel connection and signaling processing between subscribers within the module, connect the signaling messages and voice channels between subscribers of different MSC modules onto the central switching network module SNM and implement the VLR and SSP (Service switch points) functions.

5.3.5 OMM: Operation & Maintenance Module

The operation and maintenance module (OMM) is used for the management of the switching entities of the CDMA based WLL system. It is composed of three parts; system analysis, system maintenance and signaling maintenance. Its functions mainly include billing management, security management, performance measurement, service observation, fault management, configuration management, signaling tracing, clock management etc.

CHAPTER 6

6. CHOOSING A SERVICE OFFERING

Features Discussed

- Possible Components of the Service Offering
- Mobility in the Local Loop

Different technologies have different capabilities. It is important that the appropriate mix of capabilities, or services, is selected for the target market. If the total service package is insufficient, customers will migrate to competitors who offer a better serviced. If the service package is excessive, the system cost will be high and competitors can attract customers by offering as lower-cost-service.

Choosing the right mix is a task for the marketing department. They should understand the services available, the services that the potential customers say they required and the services that customers reasonably might be expected to required but do not yet realize the need, given global trends in telecommunications and local trends in growth and modernization. The marketing department needs to understand how much customers likely will pay for each of the services, the distribution of demand and the strategy that the completion is likely to adopt. One of the key trends driving increased service is the need for internet access.

Internet users often require an additional line coupled with relatively high-rate data capabilities. That will drive WLL systems to offer at least two lines in all but the least developed countries.

6.1 POSSIBLE COMPONENTS OF THE SERVICE OFFERING

6.1.1 Plain Old Telephony System (POTS)

POTS are simple voice service, which all WLL systems will provide as a minimum offering. The key concern here is voice quality. In all but the least developed markets, voice quality as good as conventional wire line will be essential.

6.1.2 ISDN

Generally, ISDN is taken to mean data at rates of 144 Kbps or higher, providing at least live lines, either of which can be used for voice or data.

6.1.3 Fax

Fax service allows the transmission of documents using international fax standards, which are designed to operate over analog phone lines, if a digital phone line is provided, conversion will be required to ensure that the fax is transmitted correctly. Because most WLL vendors provide such capabilities within their system, both analog and digital WLL systems are likely to support fax.

6.1.4 Data

Data can be supported on analog lines with modern and digital lines without a modem. The key issue is the data rate to be supported. Analog lines typically can support up to 33.6 Kbps. Digital lines can support up to whatever digital bandwidth is provided; for example, system such as Air Loop can provide up to 384 Kbps and DECT up to 552 Kbps.

Most users will not see data as service. They will have a particular application, such as the Internet and will experience certain delays depending on the data capabilities of the system. In understanding the requirements for data, it is necessary to understand the use to which subscribers will put the system. That may entail understanding computer file transfer requirements and the data sent by some in-house packages.

6.1.5 Videophone

Videophone is a much talked-about service, which few providers, as yet, have adopted. It requires a data capability from the network of around 384 Kbps or higher, depending on the quality of the picture; much lower bandwidths are possible but tend to result in pictures that move in a jerky fashion. If it is predicted that videophone will be widely used, relatively high bandwidth data links will need to be provided. When considering the requirement for videophones, It is important to remind users that the cost of a call will be substantially greater than the cost of a voice call.

6.1.6 Supplementary Service

Supplementary services include a host of features, for example;

- Caller ID;
- Call-back-when-free;
- Call diverts;
- Follow-me service;
- Advice of change;
- Divert to voice mail;
- Call waiting;
- Baring of certain incoming and outgoing calls.

The list of possible supplementary services is almost endless. Supplementary services are supported in the switch, so if there is a requirement to upgrade supplementary services at a later date, the appropriate software can normally be installed on the switch. If the switch cannot handle the features, the cost per subscriber of replacing the switch is relatively low.

6.1.7 Centrex

Centrex is a service provided to business whereby instead of installing an office PABX, allowing, among other things, office workers to call each other using typically only three or four-digit dialing codes, all calls are routed to the central switch, which acts like a PABX. The switch recognizes that the call has come from a particular office and decodes the short dialing number before routing the call to the appropriate person the office. Centre service provides savings for the company, which no longer needs to busy and maintain a PABX and may offer better services. Although it provides increased revenue to the operator, it means that the operator needs to provide significant capacity on the air interface free of charge to route calls in a trombone from one user in the company back to another.

6.1.8 Operator Services

Going one stage beyond than Centre, some networks will provide an operator service, where callers phoning the switchboard number of a company are connected to an operator employed by the WLL operator and located central to a number of companies. The operator takes the call and forwards it as appropriate. That allows the company to reduce staff requirements and because the central operator can act as a switch board operator for a number of companies, staff efficiency can be improved.

6.1.9 Multiple Lines

If a subscriber is provided with more than one line, then line can be used for fax or data, without preventing the other line from being used for incoming or outgoing call. Most residential customers do not now to multiple lines because the cost typically is twice that for a normal line. Offering multiple lines at a discount could be an appropriate marketing strategy. Most proprietary WLL technologies offer the facility of dual lies to subscribers.

Businesses, of course, will require numerous lines, typically 2 to 14, sometimes more System capable of providing that capacity are available but typically are configured for the business market alone. High-capacity systems often are realized through the use of point-to-point microwave links in the 13 or 22 GHz band.

6.1.10 Leased Lines

The concept of a leased line is a difficult one in WLL and worth exploring in more detail. The idea stems from the terrifying principles on existing systems. Generally speaking, telephony is terrified on the basis of the amount of traffic generated. For users generating extremely high amounts of traffic, the PTO typically offers them a tariff where hey can “lease” a dedicated line. They pay a monthly rental for the line (which is much greater than the monthly connection fee) but do not incur any call charges, regardless of how much information they send down the line. Users who lease a line are inclined to think they “own” the lines and that there should be no blocking on the lines. In practice, inn a wired network, everyone has a dedicated lie up to the switch, regardless of whether they decide to lease it or not, block then can occur in the switch on the lines. Nevertheless, there is an expectation of a better service from a leased line than might be experienced from a leased line.

In WLL network, the concept of a leased line is stretched even more thinly, because short of permanently reserving a slot on the air interface for a particular user. There is no concept of a dedicated resource that the user can ‘lease’ Leasing simply becomes a different tariff package whereby the user elects to pay a high monthly fee and no call charges. Operators might like to offer such a package since it will accord with the manner in which large businesses currently pay for their communications. The difficulty arises if the user expects a better service as a result of leasing the line. In q typical WLL system, the same level of blocking an experienced by all users, so it will be difficult to differentiate between leased line users and normal users. In such a system, if a better grade of service is required for the leased line users, they need to be on a different bearer.

A better solution is to make use of priority and preemption. The network would recognize that a leased-line user wished to access the network, should accord that user a higher priority and would preempt the call of a lower-priority user to make the resources available. Operator will want to use such a tactic with care. Users become significantly more upset by a call that drops out part way through than by a failed attempt to start a call if better service is offered to one user, it is possible that another user will become dissatisfied.

A compromise is to keep a number of channels free for higher priority user. When all the other channels are busy, a low-priority user will-be blocked from the network when attempting to set up a call. Higher priority user, however, will be able to access the spare channels. The number of channels reserved in that manner is a difficult choice too high and the air interface resources are badly used, too low and high-priority user still will be blocked. Cellular operators have considerable expertise in setting that number because they tend to leave a pool of channels for subscribers handing over from nearby cells.

6.1.11 Internet Service Provision.

As well as having a line offering data capabilities. Internet users will need to have a subscription with an Internet service provider that provides their gateway into the internet. A WWL operator could provide that value-added service to the customer.

6.1.12 Long-distance and International Service

A WWL operator, in the strict sense of the word, owns the infrastructure connecting the subscribers' homes to the nearest switch. The revenue is associated with carrying telephony traffic across that segment. Whether the traffic is local or international is irrelevant the operator receives the same fee for carrying the traffic. In practice, most WLL operators also own a switch. They interconnect the switch to long-distance operators and to international gateways. When a subscriber makes a long-distance call the WLL operator routes the call from its own switch into the long-distance network. The operator charges the user for a long-distance.

Call but has to pay interconnect fees to the long-distance operator, with the result that the WLL operator typically gains little more revenue for a long-distance call than from a local call.

There are a number of possible ways to increase venue. One is for the WLL operator to deploy a long-distance network (i.e. connections between main cities). Such a deployment would be a trunk backbone network and is beyond the scope of this thesis. The simpler alternative is to negotiate an attractive interconnect agreement with the long-distance operator, allowing the WLL operator to keep a larger share of revenue from the long-distance traffic.

There is little science to an interconnect negotiation but considerable negotiating skill and the need to understand the cost structure of the long-distance carrier. Such negotiations are best left to experts who have the detailed experience of have conducted them. The importance of such negotiations should not be under estimated-a favorable interconnect agreement can make a significant difference to the network profitability.

6.2 MOBILITY IN THE LOCAL LOOP

Most WLL networks have envisaged using fixed subscriber units mounted on the outside wall of subscriber' premises with a lead connecting to a phone socket inside the house Radio, however, can provide a capability that copper cannot, mobility. Recently, a number of manufacturers and operators started to examine whether mobility should be provide in a WLL system. The reasons for considering mobility are varied. The fact that those involved in WLL typically have been involved in cellular radio certainly has had an impact. Manufacturers, particularly those using cordless technology, have stressed the added bonus of mobility in their WLL product literature. This section sets out the issues. First, it is important to define mobility:-

- Full mobility is the mobility offered by cellular radio, in that the user can expect to roam to most parts of the country and make and receive calls from a handset, Implicit in this definition is the handover of calls.
- Limited mobility is the user being able to move within a small area around the home, perhaps a radius of 1 to 2 KM and still make and receive calls. Call handover is not expected.
- No mobility is defined as phone fixed by a wire into a base unit.

The provision of mobility has the potential to add significantly to the cost of a WLL system, due to the cost of enhanced coverage and the need for additional elements in the network.

A significant enhancement in coverage is required above that for a standard WLL deployment if mobility is to be offered. Compared to mobile systems, WLL deployments achieve a gain in link budget of up to *20 dB* through the use of directional antennas mounted at roof-top level. To provide mobility in the home, a building penetration loss must also be built into the calculations; measurements have shown that for a reasonably reliable house penetration a further *20 dB* loss must be allowed. The requirement for up to an additional *40 dB* on the link budget has significant implications for the six of cells. Use of propagation models applicable to WWL suggests that a *40 dB* difference would reduce a cell size of *5 KM* without mobility to *400 M* with mobility. Experience with those deploying DECT systems has shown an even ore severe coverage restriction, from *5 KM* to *200 M* when mobility is required. In the case of DECT, 600 times more cells are required if a mobility service is to be offered over the same coverage area.

For full mobility, a number of additional network components are required, including home- and visitor-location registers and gateway switches. Functionally, such as idle mode cell election and handover, is required in the mobile and the network and the cell planning must provide sufficient overlap to allow handover to occur. For some of the WLL technologies that have been derived from cellular, that functionally will be mostly in place. For others, it will not be possible to achieve the functionality.

For limited mobility, very little in the way of additional components is required, but the network planning may need to take care of propagation phenomena such as multipath, which would not be so severe in a deployment where there is no mobility.

The major issue, though, is the coverage. For in-building coverage, between 150 and 600 times as many cells will be required. Even if mobility is restricted to outside the house, allowing the range to increase to perhaps 1.4 KM, 12 to 15 times as many cells will be required. They will add significantly to the network cost, which as a crude approximation, varies linearly with the number of cell sites.

The communications market place is a competitive one, where the PTO, cellular operators, and, in a few cities, cordless operators increasingly compete for traffic. The WLL operators will be entering into that competitive environment and need to ensure that their offerings are targeted appropriately against the different forms of service that already exist.

WLL, as a replacement for fixed loop telephony, needs to offer equally good services, including excellent voice quality (requiring a tow BER channel), potentially ISDN, and services such as call-back, call forwarding, and follow-me. There is a strong relationship between price and mobility. Users are prepared to pay more and tolerate a lower grade of service to obtain mobility. The WLL operator potentially can charge more for a service with mobility but reduce the quality of the service offered below that of wire line. If prices increase while quality decreases, user will retain their wire line phones and the WLL operator will become a mobile operator using inappropriate equipment in an inappropriate frequency band.

This analysis allowed the case for mobility to be stated quite simply. An operator needs to judge whether the additional cost it will incur in providing a service able to offer mobility can be offset by the greater call charges it can achieve, while still providing a service of equivalent quality to wire line.

CHAPTER 7

7. ROLLING OUT THE NETWORK

Features Discussed

- Selecting the Number of Cells
- Selecting the Cell Sites
- Connecting the Cells to the Switch
- Installing the Subscriber Units
- Technical Advance in WLL

7.1 SELECTING THE NUMBER OF CELLS

First a few words on terminology. There often is confusion over the use of the terms *cell sites* and *base stations.* Most of the time, cells are the same as bas stations. However, where cells are sectorized, some use the terminology that each sector is a base station (because it requires a separate transmitter). Such confusion is avoided here with this definition:
A cell site is a single location with one or more sectors. The total number of cells sites is a critical parameter for the network. It is one of the key cost driers in setting the total network cost because the main element of the network cost is the number of cells. Too many cells and the network costs will be higher than necessary. Too few cells and there will not be adequate coverage or capacity in system. Although it is possible to add additional cells later, optimal deployment might required resiting earlier cells, which will engender additional expense.

The number of cells is driven fundamentally by the business plan. The key inputs from the business plan are the following:-

- The number of home;
- The density of the home;
- The expected penetration;
- The expected traffic per home.

Those inputs are used to determine how cells are required to provide adequate capacity. The other important set of parameters is as follow:-

- The area to be covered;
- The range of the system;
- The topography of the area.

Once calculations have been made as to how many cells are required for capacity and how many for coverage, it is necessary to take the higher of the two numbers. Another way of looking at it is that it is necessary, as a minimum, to provide enough cells to cover the target area; if that does not provide sufficient capacity, more cells will be needed.
The calculation as to how many cells are required needs to be performed for each part of the country where conditions differ. That is, there is little point coming up with the required base station density for an entire state in one calculation if that state actually consists of one dense city and otherwise rural areas. The base station density would be too tow to provide adequate

capacity in the city and too high in the surrounding rural area. The calculation should be performed for areas where any of the following factors differ significantly (say, by more than 20%) from another area;

- Density of homes;
- Expected penetration;
- Traffic per subscriber.

That might result, for example, in separate calculations being performed for the financial district of the city, which has high telecommunications demand, and a neighboring area of the city that might business with lower telecommunications demand. The need to perform the calculations numerous times is not problematic in itself; as will be seen, the calculation is relatively simple and could be computed quickly on a spreadsheet. The difficulty is in obtaining the input information. Hence it is assumed that the information has been obtained as part of development of the business case. The number of cells required for coverage in a particular area is given by;

Number of cells = Size of area (km^2) x I/pi r^2

Where ***r*** is the expected cell radius in kilometers and ***I*** is
a factor that represent the inefficiency of tessellating cells.

The inefficiency factor derives from the fact that cells are not perfect hexagons, and is not always possible to select cell sites exactly where a plan would required them to be. As a result, coverage area from neighboring cells often overlap (If they do not, there is a gap in the coverage, which may need to be filled with an additional cell). The size of the inefficiency factor varies, depending on the topography, the skill of the network planer and the availability of plentiful cell sites. As a guideline, a factor of 1.5 (i.e., a 50% increase in the number of cells) would not be uncommon and a factor as high as 2 would be experienced in some situations.

The number of cells required for capacity is given by;

Number of cells = Traffic channels required / traffic channels per cells.

It is necessary to calculate both of those factors. The number of traffic channels required is given by;

Number of channels = E [number / subscribers * penetration (%) * busy
hour Erlangs per subscriber]

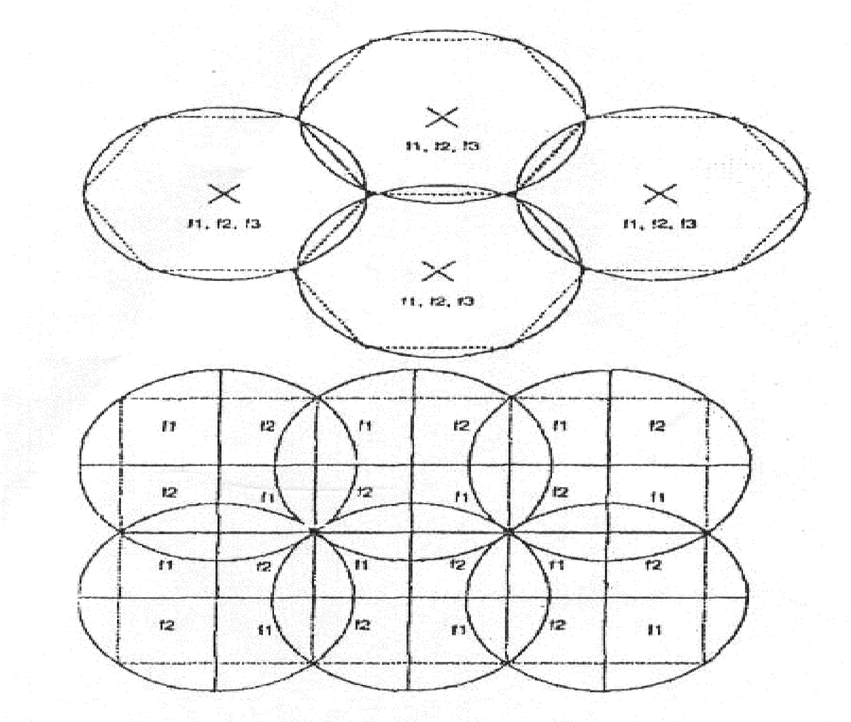
Where *E[x]* REPRESENTS THE CONVERSIN FROM Erlangs to traffic channels using the Erlang formula. That is simply a formula that describes how many radio channels are required to ensure that blocking is no worse that required for a given amount of traffic.

7.2 SELECTING THE CELL SITES

Having decided on the density of cells, it is then important to select the best cell sites. Broadly speaking, if the system is coverage constrained, then cell sites on high buildings or high areas will be important. If the system is capacity constrained, then lower buildings may be more appropriate because they will allows other buildings to act as shields, dividing cells and preventing the signal from spreading too far.

Firstly, the coverage area should be divided into a regular grid (normally a hexagonal grid), with the radius of the hexagons being the calculated cells radius as required for coverage or capacity. Base station sites then should be sought as near as possible to the centre of the nominal hexagons. With the use of a planning tool, base station sites can be tried near the centre of the nominal hexagon until one 15 found that approximates as closely as possible to the desired coverage. The process is repeated, building up the entire grid. As one base station is selected, neighboring cells may need to move increasingly from the nominal grid, such that they provide a minimal overlap with the first cells.

Once the sites have been slecte3d on the computer, they should be checked visually to make sure that the LOS paths are as predicted. Suitable mounting points for antennas should be investigated, as should equipment housing and power supplies. If all these look promising, it is time to enter into negotiation with the owner of the building for the rental of space to site the equipment.
Radio planning is a resource-intensive procedure. Depending on the complexity of the environment, the number of cells planned per person per day can vary dramatically. There are some subtleties to the cell sites; planning. The first is the use of sectorization. Instead of using an omni directional antenna providing coverage over a circle, directional antennas are deployed, splitting the coverage into a number of wedge-shaped slices-Non sectorized and sectorized cells are sown respectively.



The benefits of sectorization differ dramatically for CDMA and TDMA systems. For CDMA, sectorizing a cell results in an increase in capacity, broadly in line with the number of sectors deployed. That is because adjacent cells already use the same frequency. By splitting a cell into a number of sectors, each sector can use the same frequency. The result is that the interference to adjacent cells is increased, because there are now more users in the cell that has been sectorized. That reduces the capacity in the adjacent cell, but the reduction in capacity is much less than the gain in capacity in the cell that has been sectorized. To a first approximation, the capacity is increased in line with the increase in the number sectors.

For TDMA, the gains are much more limited. Because the base station still transmits with the same power after sectorization, neighboring cells are unable to use the same frequencies. And because additional frequencies are required in the sectorized cell (since each sector must use a different frequency), the overall number of frequencies required and, hence, the cluster size, rise. That has the effect of offsetting the gains in capacity associated with making the sectors smaller than the original cell. Careful planning using the directionality of the antennas in the sectors can result in some gains.

Each sector requires a separate base station unit, resulting in additional cost, but the site rental typically is unchanged, making the use of sectors on a single cell less costly than installing multiple small cells. Another approach is the use of hierarchical cell structures. In a hierarchical structure, an over sailing macro cell provides coverage to a large are, which typically generates more traffic than the capacity provided by the cell. Smaller micro cells or mini cells then are inserted in areas of particularly high traffic density, taking some load off the macro-cell. Such mini cells need to use a different radio frequency to avoid interference. That can be a sensible approach in a large city where the average traffic levels are low, but there is a small area in the centre with high traffic densities. If the nonhierarchical approach is adopted, then one cell would be required in the centre and perhaps six cells around it to cover the entire city. Each of the six cells would be operating at welt below capacity.

7.3 CONNECTING THE CELLS TO THE SWITCH

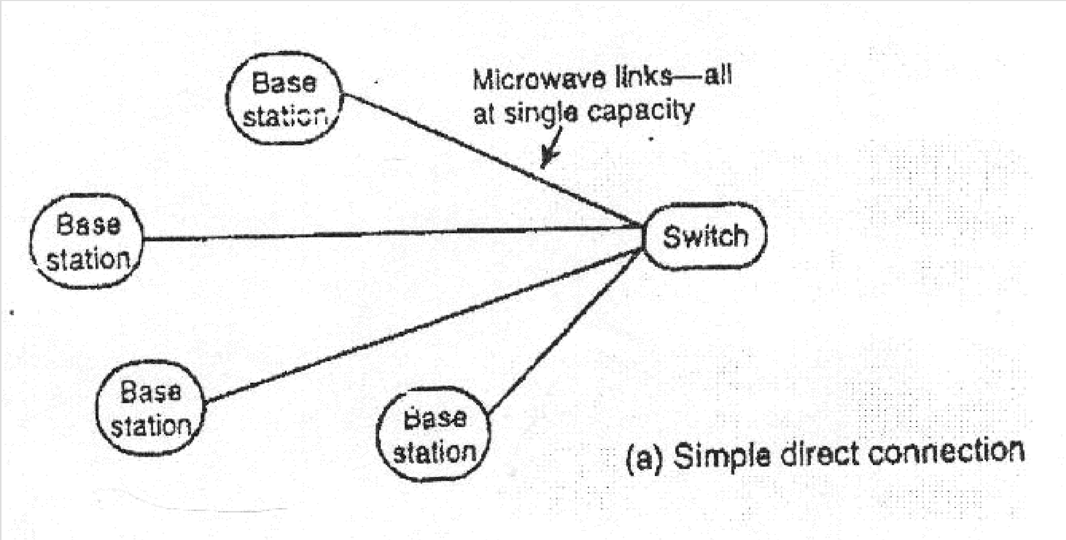
Once the cells have been selected and the cell sites commissioned, it is necessary to connect the cells to the network, typically to the switch (possibly through a bas station controller unit, depending on the architecture of the technology select). There are three general ways to do that:-

- Using a link leased from the PTO
- Using a microwave point-to-point link
- Using a satellite link

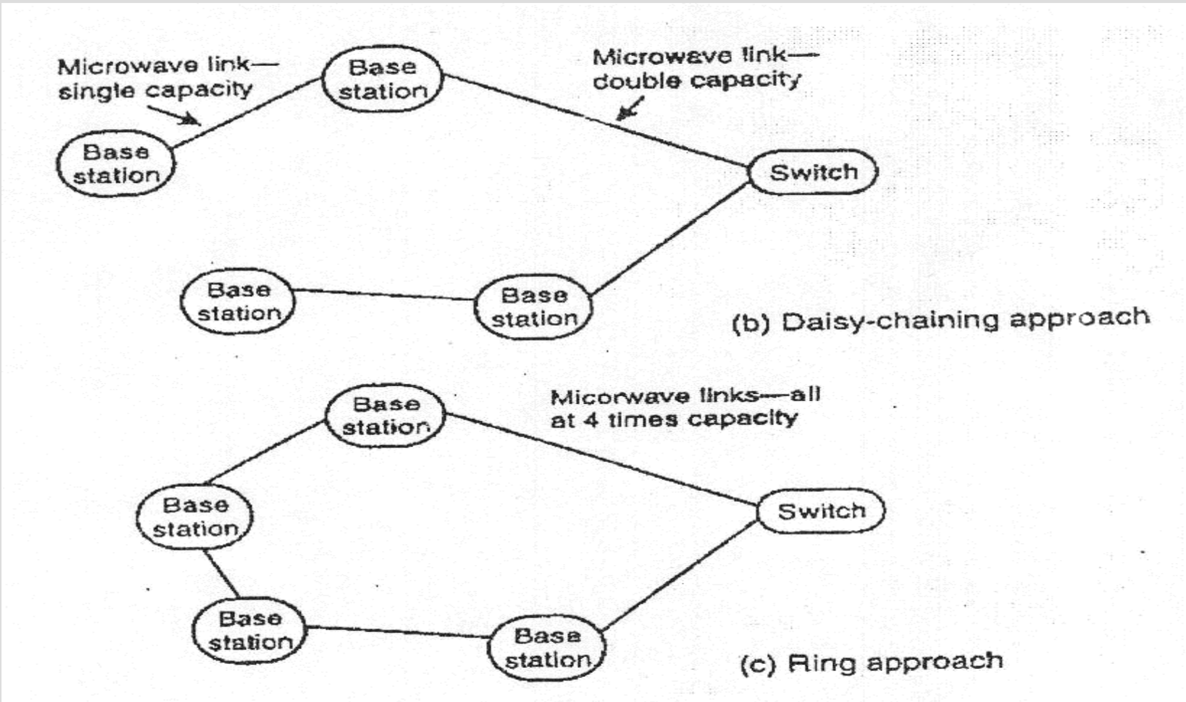
7.3.1 Leased Link

Leased link is the leasing of a line from the PTO. The line may not actually be cable-the PTO itself may be using satellite or microwave links-but that will be transparent to the operator. The operator pays an annual fee for use of the link, which typically is related to the distance over which the link runs and the capacity required from the link.

Even when the leased link is the cheapest option, operators may want to avoid it for a number of reasons. Links may not be sufficiently reliable or have a sufficiently low error rate. The operator, for competitive or whatever reasons, may want to avoid leasing key resources from a competitor they might suspect of deliberately providing an inferior service to make the competition they suffer from the WLL operator less severe.



(a) Simple direct connection



(b) Daisy-chaining approach

(c) Ring approach

A radio transmitter and a directional antenna are placed at the cell site, pointing to another directional antenna and a receiver at the switch site. Further, spectrum assignment, particularly in the lower frequency bands, may not be available.

7.3.2 Satellite Links

With the use of *very small aperture terminals* (VSATs), base stations can be linked to the switch via a satellite link. Typically, satellite links are more expensive than fixed links and cause a significant delay to the signal, which is perceived as delay or echo by the user and which is highly undesirable. However, in situations where the cell site is so remote from the switch that a number of hops on a fixed link would be required and there are no available leased lines, satellite links may form the only viable alternative.

7.3.3 Protocols Used for the Interconnection

Clearly the base station and the switch need to use the same protocol along whatever medium is used to interconnect them. The protocol describes how speech and data calls are carried on the line and sends signaling such as establish call and disconnect call.

All those protocols run over EI data links which are 2-Mbps (2.048 Mbps to be precise) links. The link is segmented into thirty-two 64 Kbps slots. Slots 0 and 16 are reserved for control data and synchronization information; hence, each EI bearer can provide up to thirty 64-KBps channels. The following main protocols are available:-

- *Channel-associated signaling* (CAS);
- *Signaling system 7* (SS7);
- Q 931;
- V5.1;
- V5.2;

CAS can carry only POTS (simple voice) traffic, while Q 931 can carry only ISDN (data) traffic. CAS suffers from one key disadvantage; it is what is termed non-concentrating. That means that for every subscriber, a time slot on the EI bearer must be permanently reserved, regardless of whether a call for that subscriber currently is in progress. Because most subscribers generate traffic only around 5% of the time, that is extremely inefficient. Its only benefit is that blocking is not possible on the base station-to-switch interface.

The V5.1 protocol also is non-concentrating, but it has the advantage of being able to carry both POTS and IDSN traffic. That is a significant advantage. In a network where both POTS and ISDN are provided (as the case for many WLL networks), if CAS and Q 931 are used, then separate EI lines would be required for CAS signaling and Q 931 signaling. If each required only half the capacity of an EI line, then without V5.1, to EI lines would be required, whereas with V5.1, only a single line would be required.

The V5.2 protocol is concentrating, so it is not necessary to dedicate resources on the EI link to any particular subscriber-they can be assigned dynamically (in the same fashion as is performed on the air interface). This allows far fewer EI links to be used, reducing the overall network cost.

If V5.2 is not used, it is possible that the system capacity is limited not by the air-interface capacity, but by the number of subscribers that can be accommodated on the EI links to the switch.

7.4 INSTALLING THE SUBSCRIBER UNITS

Most of WLL systems require an external antenna mounted at rooftop or on the side of the building to ensure a high-quality link of sufficient rang. Installation is a case of bolting the antenna to the side of the house and then running a cable, normally down the outside of the house and then into the room where the phone socket will be installed. The socket then is installed in the room and the phone connected.

On arriving at the house, the installers need to know the direction of the base station. They need to look in that direction from the house and take note of possible obstructions. If the signal strength is satisfactory, the antenna unit can be mounted, the antenna aligned to maximize signal strength and the remainder of the installation completed.

7.5 TECHNICAL ADVANCES IN WLL

Consumers are used to computers that double in power and capacity almost annually and a seemingly invincible technical revolution. Such revolutions have not occurred in the world of wireless. Although there has been a transition from analog to digital mobile telephony, the consumer benefits have not been great and the transition will take place over a 15-years period. Plans for third-generation mobile radio systems show little more than ability for the phone to master multiple different standards. Equally, early predictions of the spectrum efficiency of the newer systems generally have proved to be incorrect, with GSM only providing marginal capacity increases over TACS systems. Hence, significant technological advances enabling much more efficient use of the radio spectrum and providing valuable additional benefits to users seem unlikely.

WLL systems will add additional features and gain flexibility, but in general no major break through should be expected. Along the same lines, MMDS-type systems are likely to gain useful return channel capabilities in the next few years. That would be an interesting development, since an operator deploying such a system would be able to provide both broadcast entertainment and telephony from a cost base probably only allow a lower cost integrated service, which would seem attractive (subject to the availability of broadcast material through other media such as digital terrestrial and digital satellite broadcasting). With technical developments helping to overcome some of the effects of rain fading, these high-frequencies, high-capacity systems will be highly attractive within a decade.

APPENDIX

Appendix A: List of Acronyms

ADPCM	Adaptive differential Pulse Code Modulation
AMPS	Advanced Mobile Phone Service
ARIB	Association of Radio Industries and Businesses
AUC	Authentication Centre
BSC	Base Station Controller
BSS	Base Station Subsystem
BTS	Base Transceiver Station
CCK	Communication Commission of Kenya
CDMA	Code Division Multiple Access
CO	Central Office
CPE	Customer Premise Equipment
CT-2	Cordless Telephony System – 2
DAMPS	Digital Advanced Mobile Phone Service
DCA	Dynamic Channel Allocation
DCS	Digital Cellular System
DECT	Digital European Cordless Telephone
EDGE	Enhanced Data Rates for GSM Evolution
EIA	Electronic Industries Association
EIR	Equipment Identity Register
ETACS	Enhances Total Access Communication System
ETRI	Electronic and Telecommunication Research Institute
ETSI	European Telecommunications Standards Institute
FCC	Federal Communication Commission
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
GGSN	Gateway GPRS Support Node
GMPCS	Global Mobile Personal Communications Services
GMSK	Gaussian Minimum Shift Keying
GPRS	General Packet Radio Services

GPS Global Positioning System

GSM Global System for Mobile Communication

HDR High Data Rate

HLR Home Location Register

HSCSD High Speed Circuit Switched Data

IMEI International Mobile Equipment Identity

IMT International Mobile Telecommunications

IP Internet Protocol

ISI Intersymbol interference

IS-95 industry Standard 95

ISDN integrated Services Digital Network

ISP internet Service Provider

ITC Internet and Telecoms Convergence Consortium

ITU International Telecommunication Union

LAN Local Area Network

LMDS Local Multipoint Distribution Service

MMDS Multi channel Multipoint Distribution Service

MSC Mobile Switching Centre

MVDS Microwave Video Distribution Systems

NAMPS Narrowband Advanced Mobile Phone Service

NMT Nordic Mobile Telephone

OMC Operation Maintenance Centre

OSS Operation and Support System

PABX Private Access Branch Exchange

PCS Personal Communication Systems

PCM Pulse Code Modulation

PDP Packet Data Protocol

PHS Personal Handy-Phone System

PM Phase Modulation

PN Pseudo-random Noise

POP Point-of-Presence

POTS Plain Old Telephone Service

PSTN Public Switched Telephone Network

RF	Radio Frequency
RPE-LTP	Regular pulse Excited-Long Term Prediction
RTT	Radio Transmission Technologies
SGSN	Serving GPRS Support Node
SIM	Subscriber Identity Module
SMS	Short Message Service
SS7	Signaling System 7
STD	Subscribers Trunk Dialing
TACS	Total Access Communication System
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TIA	Telecommunication Industry Association
VTIA	Volunteers in Technical Assistance
VLR	Visitor Location Register
WCDMA	Wideband CDMA
WLL	Wireless Local Loop

Appendix B: References

Martin P Clark. “Wireless Access Network”

Freeman, Roger. “Telecommunication System Engineering”

Theodore S Rapaport. “Wireless Communication, Principles and Practice

Calhoum, C. “Wireless Access and the Local Telephone Network”, Norweood, MA; Artech House

Steele R. “Mobile Radio Communication”, New York; Wiley & Sons

Lee W. C. Y “Spectrum Efficiency in Cellular”

Mouly M. M-B Paualet “The GSM System for Mobile Communication”

Schwartz M. Telecommunication Network – Protocols, Modeling and Analysis”

Webb, Walliam “Introduction to Wireless Local Loop” Artech House Publishers’
Norwood, Massachusetts, USA

Jhong, Lee and Miller Leonard. “CDMA Systems Engineering Hand Book”, Mobile Communication Series, Artech House Publishers

Megarty, Terrence “The Economic Viability of Wireless Local loop and its impact on Universal Service”, Columbia University

Dayem, Rifat. “PCS and Digital Cellular Technologies, Assessing Your Option” Prentice Hall, New Jersey, USA

“Wireless Local Loop Technology Standards Overview”.
“http//www.telcomresearch.com/overview.html”

Economic Report: “ Fixed Wireless Network” How Technology Impacts Success in Southeast Asia. Qualcom Report prepared by Pittiglio Rabin Todd & MeGrath (PRTM) Consultants, California, USA.

”Welcome to the Future: The Third-Generation Mobile Communications Starts Here” Mobile Communications Asia. Ericsson, Sweden.

Farley, Tom “Digital Wireless Basics”,
http//www. Privateline.cpm/PCS/history.htm

Goodman, David J “Wireless Personal Communication Systems”, Addison-Wesley Communications Series, Reading, Massachusetts, USA

Compag Digital Products and Services “GSM: Overview and Principles”
http//www digital commu/customers/solutions/customized solutions/whitepapers gsm.htm
IEC “Global System for Mobile Communication (GSM) Tutorial”
http/ww. Webproforum com/iec04/index.html. International Engineering Consortium, Chicago, Illinois, USA.

IEC, “Narrowband Analog Mobile Phone Service (NAMPS)”, http://www.webproforum. Com/sponsorme2/topic04.html. International Engineering Consortium, Chicago, Illinois, USA

IEC, “Personal Communication Services Tutorial”.
http.//www.webproforum .com/sponsormel/index.html, International Engineering Consortium, Chicago, Illinois, USA.

IEC “North American Analog Cellular Systems”
http.//www.webproforum .com/sponsormel/index.html, International Engineering Consortium, Chicago, Illinois, USA.

“Signaling System 7 (SS 7) Tutorial” Web ProForum Tutorial Volume 1.
http.//www.iec.org. International /engineering Consortium, Chicgo, Illinois, USA

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