CELLULAR AREA COVERAGE TRANSPORT NETWORKS

Donald V. Lemke, WB9MJN
1529 Clyde Drive
Naperville,IL 60565
@ WB9MJN

Abstract

With the advent of level 3 software becoming widely available to Ham Packet Radio, a complete rethink of transport radio systems can lead to greater thruput improvements. This paper details a cellular area coverage transport system. Designed to be collision-free, and not significantly effected by modem lock-up times, this radio system would have thruput equivalent to modem data rate.

System Purpose and Considerations

Packet radio needs much higher thruput networks in many parts of the country. In the urban areas, the problem is too many stations on a each multiple access channel. Here, mainly CSMA (Carrier Sense Multiple Access) collisions reduce thruputs on multiple access channels, making them highly unuseable for thru traffic. In rural areas, there may be fewer stations on a given channel, but they are much more likely to be hidden from each other due to terrain or distance, causing the network thruput to follow the ALOHA theoretical predictions.

Many groups in packet have long decided to have a network for transport separate from user access. While this is a step forward, these networks are designed at present to be multiple access as well. This can result in a 3 (worse case CSMA thruput) to 6 (worse case ALOHA thruput) times reduction in thruput at full load. Just when the network needs to be most efficient, it is the least efficient. The functions of the transport network, and the user access node are significantly different, that much thruput can being thrown away by copying the user access station configuration. This is regardless of any data rate increase on the transport network, and simply a matter of statistical effects of multiple access in the radio environment. 1200 baud packet has a thruput of 500 baud with 256 byte packets, and .3 sec TXD. On an ALOHA channel under full load, such as 145.01, this drops to 85 baud. For the full load to become locked in, a thruput demand by several stations of 250 baud or more is all that is required.

Most of the present transport network projects are basically point-to-point. This causes some difficulties with human nature. Many people feel alienated from groups, whose previous history have directed them into building networks that are not close-to-home. Close-to-home is a highly subjective thing. It may mean literally the closeness to ones home QTH, or it may mean the closeness to ones desired direction for the network to go. Many packet users fail to support network construction efforts because of this I believe. A technological solution to this would address area coverage. If a network existed which was almost transparent in transporting data from an area, which is necessarily not immediately close to a point-to-point transport network site, support from that area would then be forth coming. I am continualy amazed at the failure of people who live in river valleys to accept the physics of radio propagation and topology. An area coverage network between the user and the point-to-point network should gain much support from the WIIMBY (Why Isn't It My Back Yard) set, and also help to off-load traffic from the necessarily low data rate (rf margins vs. money problems) point-to-point links.

Much of the packet revolution on ham radio remains unexplored, at least unexplored on-the-air. Multi-user mailboxes and file servers, wide area coverage conferencing, digital voice, graphics, reliable medium range real time communications, are yet to be applied widely. The main reason for this, is that packet thruput is much too meager to support these applications.

Packet resources pulling on volunteer time and effort, have very long lead times till installation. Therefore, it makes sense to try to improve thruput as much as possible per improvment cycle. To this end, this proposal makes no compromises on thruput. The end result is more expensive than other possibilities, but not unachievably so for cooperating ham clubs. The additional expense does pay for a system with more quality than other systems, resulting in a higher thruput/cost ratio in doing the area coverage job.

Single Access

A single access channel is one in which only one transmitter is allowed at any given time. A single access link network would be collision free. Such a network provides the largest thruput, for a given data rate modem.

There are many ways to do single access. Token passing, polling, and frequency multiplexing are the ones that come to mind. In the ham environment, where a variety of protocols exist, the software techniques of token passing, and polling have a political burden associated with them that would probably prevent widespread use of compatible links. Additionally, these techniques do slow thruput slightly over frequency multiplexing.

Frequency multiplexing of link stations would be the ideal way to provide single access links. It can be used with any protocal, and provides the best thruput. Frequency multiplexing is expensive tho, on first glance.

Full Duplex

Full duplex operation, using existing ham modems at data rates 56 kBd or higher, can more than double one-way thruputs. It is expected that higher speed modems will will require the same or more bits to lock onto incoming signals. More sensitive modems require many more lock-up bits. By keying a link transmitter for the duration of a QSO, modulated with sync pulses, the thruput from one node to the next, will be more than double, just because the receiving modem and digital phase lock loop (DPLL) won't need to need to lock up on each frame. For Example the WA4DSY 56 kBd modem takes an estimated 15 msec to lock-up. With the typical 256 byte-packet, this is a thruput of 13 kBd, without considering ack time.

While it may be argued that with widespread busy network use, each packet would rarely be small, this hasn't been observed where the network covers a wide area, and and the entire paths of the simultaneous QSO's are often not coincident. Additionally, network and link layer acks are small frames, and even putting many of them into a packet results in short packets. There is no way to really control packet size, without introducing additional delays for the individual user. Thus, simplex is extremly inefficient for our area coverage transport networks at 56 kBd or above.

With the addition of coherent demodulators, a full duplex link can run at lower power levels than a simplex network. The increased lock-up time of these demodulators would be negligible in a full duplex transport network. Altho at VHF and UHF frequencies it may be cheaper to improve transmitter power, above 1296 MHz this might not be the case. The RF loss of the frequency multiplexing device, commonly called the "duplexer", as compared to the loss of a PIN diode T/R switch, is small. Typically, the duplexer has 3/4 dB more loss than the T/R switch over the VHF/UHF spectrum. This difference in loss is even smaller at microwave frequencies.

The cost of frequency multiplex drops dramatically with increasing frequency. At the same time the bandwidth thru the rf hardware increases and the range per hop thru omni-directional antennas falls.

Examples

In the introduction above I figured that 145.01 under full load would have a thruput of 85 baud. The thruput of a 1200 baud transport network that was both full duplex, and single access would be 1200 baud. This is a 14 times improvement without improving data rate. At 9600 baud the network would be 113 times as fast as 145.01 and 56 kBd would be 659 times as fast. At 224 kBd, the network would be able to handle two channels of 56 kBd PCM, as well as 112 kBd of data thruput at a whopping 2635 times improvement over 145.01! Think about a network that interlinks many of the voice repeaters in an area with dial up digital voice links, as well as hi-speed digital LAN's?! This is so removed from the realm of the present day Ham reality, I hope you don't all think this is a "pipe" dream. The numbers don't lie though, and this could very well be done with a 224 kBd version of the network detailed below.

Cellular Transport Network (Cellnet)

To do area coverage, one needs a mesh of nodes. To do a mesh of nodes with full duplex, and single access channels in frequency multiplex, one can assign each geographical location a frequency of its own. Since there are far fewer frequencies than geographical locations, some scheme for frequency reuse is needed. To reduce costs, each node should have the fewest number of receivers, and thus neighbors. Additionally, its desirable that any two points geographically separated by the same distance will have the same propagation time between them, within the network, as any other two points separated by that same distance.

Area coverage cannot be done with one link per node. It is possible to do area coverage with two links per node by drawing a line with the links, and then rastering back with another line at the boundary of the area. This has three problems tho. First, a station in one raster line would need to send packets to the end of his raster to get to the neighboring raster. Thus, significant propagation delays could be incured by relatively close geographical neighbors. This is less reliable as well, since relatively short range communication requires the participation of many link stations. Third, a network built to cover an existing demand area, might not be easily modified to cover extensions to that area in the future.

A three link per node scheme meets all the requirements. Paths between any two nodes are relatively direct, and area coverage is achievable. If one starts with several three pointed stars with 120 degrees spacing between rays (like the Mercedes-Benz symbol) and makes a pattern with them, there is one arrangement that can repeat itself ad infinitum, without any of the rays crossing. This pattern of hexagons is shown in Figure 2.

Full duplex can be done with this scheme if each node has two independent RF bands and that each node's transmitter is on the opposite frequency band from it's neighbors' transmitters. The two independent RF bands needed per site can be achieved with separate antennas and two ham bands or with a single antenna and duplexer. At UHF and lower microwave bands the cost of **feedline** is more than the duplexer. At VHF, the only available spectrum, that might be used for this is on a single band. For an omnidirectional antenna **cellnet,** a single ham band and duplexer is the best course to acheive the two independent frequency bands. See Figures 2 and 3 for a typical spectrum and geographical layout. The node numbers in the two figures correspond.

The next question is **"How** many discrete frequencies are needed to implement this network?". At a certain range it is safe to reuse a frequency without interference to other net members. I have no common **sense,** or **mathemetical** explanation, but by laying out a large network on a piece of paper, I was able to figure that 5 channels in each of the independent frequency bands was the minimum required. With 5 channels the closest node that transmits on any of the receive channels of a particular node, is 3.4 times the node spacing away from the particular node.

If antenna heights are adjusted to give **grazing or** slightly lower paths, the signal strength of the more distant transmitters should not effect proper reception of node neighbors, since they will be significantly occulted by the bulge of the earth. In troublesome terrains where it may not be possible to mount antennas low enough, **downtilt** and combined beam antennas may be needed. Generally, in most areas, a simple omni antenna will be sufficient. Mounting antennas too low is also a mistake, as the power required to overcome the bulge of the earth reliably, will cause the station to be heard too far away during periods of propagation **enhancements.** This is a common problem on 145.01.

Table 1 details the RF link margins for 220, 440 and 1250 MHz Ham bands and various node spacings. 2 meters and 440 **MHz** are considered the obvious candidates for user access stations which would have to be **colocated** along with the **cellnet** link equipment at the same site. 900 **MHz,** which could have the greatest usage in metropolitan **areas,** is also shared with truck location systems. Due to the interrelation of frequencies within **Cellnet,** it was deemed impractical to set up a network, with the possibilty of the **primary** *use* truck location system coming along and using one of the frequencies. The whole network would then need to be recrystalled, and possibly shifted up or down slightly in frequency, to fit all the channels in the duplexer pass band. Unfortunately, the **neccassary** spectrum in the 220 band to **impliment** a **cellnet** there has **been** stripped arbitrarily from the Amateur allocations in the U.S.. Table **1** was done before this **occured.** A 1250 **Cellnet** could use 440 for user access **,** and a 440'cellnet could use 2 meters. 220 MHz and 900 MHz could be used for rural user **access,** but without a major change in coordination of existing ham and commercial facilities, it would be difficult to use these bands for this in urban areas. Of course, if a 220 repeater owner/operator wishes to change the emphasis of his existing equipment and coordination to packet, the previous sentence does not apply. In the Chicago area, only one or two systems have so changed, and this is too few to support an entire **cellnet.**

Notice in Table 1, that antenna heights are adjusted to give a grazing path when refraction causes the earth's radius to be **4/3** x the actual radius. This and the **assumption** that the antenna positions at the two sites are at equal heights above the midpoint terrain, simplified the determination of the additional **path loss** due to Fresnel effects using Reference 1, Figure 8. The lengths of feedline, and **thus the feedline** loss was adjusted with these antenna heights. Rooftop installations were assumed to require 50 feet of cable to reach the antenna. The cable loss figures are for **7/8t** inch Heliax **(tm).** The duplexer was assumed to have a 1.5 **dB** one way loss. Antenna noise temperature at 220 **MHz** was assumed to be 10,000 degrees Kelvin, 3,000 degrees Kelvin at 450 and at 1250, 290 degrees Kelvin. These values were determined from the Reference 2, Page 29-2, Figure 1, and are representative of suburban RF environments. The **WA4DSY** modem **was** used for the reference demodulator in these calculations. The **transverter** used in **WA4DSY's** tests has a noise figure of 4 **dB.** Thus, the noise power of his test, assuming a 80 KHz IF noise bandwidth, is -121 **dBM.** Thus for a **1/1000** BER, the RF signal to noise margin needs to be 13 **dB.** **1/1000** BER represents a frame of 500 bytes failing to be copied half the time. It is estimated that a 20 **dB** margin above this point will result in the average 500 byte frame being copied 99 % of the time. These details are used in the equations below:

Total Path Loss **=** Free Space Loss **+** Fresnel loss + (2 X Cable Loss) + Duplexer Loss
(dB)

Free Space Loss **=** 36.6 **+** 20 **log(miles) +** 20 **log(MHz)**
(as)

Fresnel Loss determined from Reference 1.

Cable Loss
@ 220 MHz =.0055(Tower height in feet + 50)
@ 450 MHz =.0080(Tower height in feet + 50)
@ 1250 MHz =.015 (Tower height in feet + 50)
(single station cable loss, multiply by 2 for system cable losses)

Duplexer Loss = 3.0 dB
(includes transmitter to antenna loss at one station, and antenna to receiver loss at the other)

Receiver Noise Power = 198.6 + 10 log(B) + 10 log(Te)
(dBm)

B = Bandwidth in hz = 80,000

Te = Receiver Noise Temperature (degrees K)
= Tant + (LF-1)Tamb

Tant = Antenna Noise Temperature (degrees K)
= 10,00 @ 220 MHz
= 3,000 @ 450 MHZ
= 290 @ 1250 MHz

L = Rx duplexer loss + Rx station cable loss
@ 220 MHz
= 1.5 + .0055 (Tower height in feet + 50)
@ 450 MHZ
= 1.5 + .0080 (Tower height in feet + 50)
@ 1250 MHz
= 1.5 + .0150 (Tower height in feet + 50)

F = Receiver Noise Factor
= Antilog (Noise figure/lo)
= 2.5 (for 4dB NF)

RF power for 20 dB margin = Receiver Noise Power + Modem 1/1000 BER S/N + 20 dB + Total Path Loss - TX Antenna gain - RX Antenna gain

Modem 1/1000 BER S/N = 13 dB
(for WA4DSY modem)

Tx Antenna gain = RX Antenna Gain
= 8.1 dBi @ 220 MHZ
= 11.1 dBi @ 450 MHz
= 11.1 dBi @ 1250 MHz

Based on Table 1 and practical considerations, three versions of the Cellnet look promising. Rural versions of Cellnet using 45 miles spacing and 220 or 450 MHz at 56 kBd. An urban version at 1250 Hz using 56 to 224 kBd at 15 mile spacing provides enough bandwidth for expected thruput increase and the possibility of using 220 or 440 MHz 9600 baud or 19.2 kBd user access. The rural version would need an antenna with a height of 250 ft above average terrain. Sites with this height are much more common than sites that could support longer distances. At 220 MHz 70 watts with the WA4DSY modem and a 6dBd antenna is needed. At 440 MHz, 40 watts with the same modem, and a 9 dBd antenna. The urban version at 56 kBd would need essentially tree clearing antenna heights, and 12 watts. The 224 kBd version, assuming the modem is coherent detection, would need 24 watts and if not coherent, 48 watts. All these powers are for 20 dB margin, Since we have the ability to retry bad data in packet, and the cellnet concept allows easy rerouting if there is a link outage, this should be sufficient margin.

The 220 MHz Cellnet is now impractical with the short-sighted reallocation of the lower 2 MHz of that band.

The MACC (Mid-America Coordination Council) is recomending a duplex link band from 440 to 442 and from 445 to 447. Rural Cellnet would need a 1/2 MHz in each of these bands. Unfortunately, ATV is commonly used in this spectrum. Hopefully, ATV operations can be moved to the two 6 MHz channels between 420 and 432 MHz. This means that the many present ATV repeaters would not be able to operate full duplex anymore. The impact of the FCC decision is now reaping its practical consequences. It would be quite a technical challenge to put a full duplex ATV repeater on the air using the two neighboring ATV channels, but it can be done. Seperate Tx and RX sites a:nd a link between the two would be necessary. Additionally, 438 to 440 could then be used for the control links from the 220 to 222 spectrum displaced by the recent FCC action.

Two 2 MHz bands are (available in the digital portions of the 1250 MHz ham band. 1298 to 1300 MHz in the h.i-side band, and 1249 to 1251 provide the best spacing from other band users, and conform to the 1988-1989 ARRL repeater directory listing of suggested usage. These bands would be broken into the 5 Cellnet channels, each channel being 400 KHz. There is still plenty of spectrum in the ARRL suggested digital allocation for point-to-point digital links. Appendix 1 details a realizable local oscilator scheme to support the 1250 MHz Cellnet bands. An aside; curves for the duplexer mentioned in Appendix 2 show it has a 2 MHz bandpass, which is enough for five 224 kBd channels.

Figures 4 and 4a show two general schemes to do Cellnet. While these are achievable now, RF and computer development could reduce the cost of these implementations.

Appendix 2 details a 56 kBd, 1250 MHz, 15 mile node spacing RF hardware complement, and its cost. $1400 dollars to talk 15 miles away may seem like a lot. Much of this stuff can be scrounged tho. Antennas and duplexers are good projects to be home made, but extensive testing would be required on working prototypes to ensure reliability. Much of the cost is in feedline, connectors and the duplexer.

While the figure shows the computer system that is available today off-the-shelf, most computer people I show this to, frown, go back in their closets, pull out a dusty **Multibus (tm)** card, and **say"Let** me at **it"!** Franklin Antonio and friends' PS-186 switch would be an ideal **Cellnet** controller. The Chicago Area Packet Association **(CAPRA)** has been working on a 68000 based Multi-bus card general purpose packet switch project for a long time. This project could be used as a **Cellnet** controller. A **Cellnet** controller from whatever source, should drop to $500 or less if/when it is fully developed. **I** remember buying a $400 dollar TNC 1 kit, not so long ago, so **I** have good hopes that this kind of cost reduction will occur.

Cellnet and Refraction

While the above calculations predict the average path loss to the neighbor nodes, the path losses can vary widely. During extremes of propagation the signal strengths of the nodes that reuse the frequency even tho they are far over the geographical horizon, **may** not be insignificant. There are various remedies and techniques that can insure that enhnaced propagation has minimal effect on network reliability.

Coherent demodulation has better capture effect than noncoherent demodulation. Steve Goode, **K9NG,** said that one version of an MSK modem he was working on had a -7 **dB** interference tolerance, in coherent form, but only a -14 **dB** in non-coherent form. While this modem was not identical to the **WA4DSY** modem, it shows that the coherent demodulation has a much improved capture effect. This is an important feature in a **cellnet** system in overcoming tropospheric refraction variations, commonly called local enhancement openings. Although not the worse **case,** we can estimate that during such **openings,** the earth is propagationally flat for the distances involved. In free space, the signal 'strength difference between the desired signal, and the closest reuse of this frequency at a distance of 3.4 x the node spacing is 10.6 **dB.** Using Reference 1 Figure 2, we see that for a 15 mile node spacing and 28 foot high antenna, the difference is about 20 **dB** for flat earth. These figures must be viewed as only rough estimates. Blockage effects could improve or degrade the ratio significantly. If **siteing** is done so that no blockage occurs between neighboring nodes, then the ratio will be improved.

Super-refractive conditions also occur. During these periods, refracted and direct signals from the desired station may cause destructive interference, reducing its signal strength, while increasing the signal strength of the interfering signal. Luckily, for **Cellnet,** these periods of time are a small fraction on a yearly average. Switching to packet length transmissions, and **CSMA** may provide better thruput during super-refraction episodes. Dynamic routing should prevent any node from losing contact with the network. With time and effort, all these conditions should be able to be handled automatically by the site controller computer. Observation of what each demodulator is decoding and the channel signal strength, qualified by DCD should provide sufficient information. When strong data signals occur, and no packets are decoded on a channel, a site controller would ask the neighbor on that particular channel, and the interfering station to switch to **CSMA.** The interfering station could either be observed after the neighbor switched to **CSMA,** or deduced from programmed network knowledge. Use of coherent demodulation should greatly reduce the periods of time these measures would be necessary. Field tests may show that with coherent demodulators, the above techniques are unnecessary.

User Access.

As the **Cellnet** transport network has no direct RF access by users, a data radio system on a separate, and independent channel is required for this. A variety of user access schemes are available. The site controller then combines the users, traffic into a single stream for transport thru the **Cellnet** radio system.

For the rural **Cellnet** scheme, I believe a 2 meter 1200 baud, AFSK, half-duplex, regenerative digipeater would be best. This scheme would use an RF arrangement similar to the average voice repeater. Incoming demodulated data would be squared-up before applying it to the transmitter's modem. The **Cellnet** controller would be **or'd** into both Tx and Rx data streams, and would have logic to inhibit transmissions when the Rx channel was busy. Such a system would eliminate hidden station affects, a big problem with **scatered** users, all with beam antennas pointed at the site. It would probably provide the first LAN style operation many rural **packeteers** will have experienced. The shift from ALOHA to **CSMA** thruputs, and the absence of data resend time would quadruple rural LAN thruputs. All this without any modification of user equipment.

For urban **Cellnet,** I like 440 MHz, 9600 baud **K9NG** simplex user access. Since the cells are relatively small, most users will DCD each other, and CSMA is in effect. 9600 baud **K9NG** modulation should be able to operate in the 25 KHz channelization on 440. Radios with 15 to 20 KHz IF filters are needed. User radios for this would need to be older crystalled radios. Most new PLL radios do not have quick enough turnaround. Surplus commercial radios such as Motorola MAXAR, FLEXAR, and **MICOR** might be used if the IF bandwidths are wide enough. When 224 **kBd** transport nets are in place, 900 MHz, **56kBd, WA4DSY** simplex may be more appropriate. Following the same logic as with rural **cellnet,** only 5 channels for user access would be needed.

GLB radios should be easy to modify for **K9NG** modulation. AEA radios could be used for this too. **It's** really a shame, that these companies decided on conflicting modulation standards, when the **K9NG** standard has been in place for such a long time. Now, there are very few hi-speed packet stations.

A newcomer to high speed packet feels he needs to be a modulation expert, just to buy a radio. Its just a fracticnalization, packet can do without and everybody has lost. TAPR could have helped to prevent this too. Think where we would be-now if the TNC2 had 2 versions, the original, and a version with a K9NG modem on it! Yep, that s right, the K9NG modem is older than the TNC2! It really is unfortunate that many people did much to create a perception of imperfection surrounding the K9NG modem, which is completely unfounded. This was confused by many others to include the K9NG modulation standard as well. The K9NG modem works well when matched to the radio. In this respect, the K9NG modem is no different than the original TNC2 AFSK modem. The filtering in the radio and modem needs to be designed correctly, with proper consideration of the receiver IF bandwidth. Now we have two reinvented wheels, and a hard choice between the three modems. An improved modem redesign is now being done by our British compatriots, instead of American companies. The use of a switched capacitor filter, and resistor header has been apparent to us as the best way to get around the various IF bandwidths of off-the-shelf radios and use of the modem at other baud rates, for sometime. The British project should result in good modem performance improvements. End of Soapbox speech. I have to admit, not many thought that the TNC2 with 5 MHz clock would work at 9600 baud, but several are in operation around Chicago, using K9NG modems, with either Howie version 1.1.5 or Net/ROM.

Digital Audio Applications

Many repeater systems have extensive auxiliary links to support extended operating ranges. Frequencies used for this burden our allocations. Now, I'm not talking about the repeater that uses one auxiliary link to link its receiver to its transmitter site. I'm talking about the repeater that has 2 or more remote receivers and a 2 meter transmitter high enough and powerful enough to let HTs hear it in all of the remote receiver zones. 'With several repeaters connected by Cellnet in dial-up fashion, a large coverage area can be had for each repeater% users, without each repeater needing its own set of auxiliary link channels and the powerful transmitter. Although wide area coverage would not always be available, as somebody might be using the target repeater, the ability to talk thru ranges much farther distant than an independent link system could provide, makes up for this problem. Its conceivable that during low usage hours, with an HT, one could easily talk anywhere in a metropolitan area, with a rubber duck and without any propagation enhancement. This capability here in the Chicago area now, requires a 40 foot high antenna, and 40 watts. Generally tho, only one, or two Cellnet hops links could be guaranteed. Don't get me wrong now, even tho Cellnet would be ideal for a repeater without any remote receivers and auxiliary links, repeaters with links would still benefit by gaining the capability to talk to and thru neighboring repeaters.

Error corrected .PCM voice can be sent with differential coding in 24 kBd of audio bits. Some overhead for error detection would be needed, Uncorrected PCM needs 56 kBd audio bits, and no overhead. Thus, 112 kBd could probably support 2 or 3 audio channels. Uncorrected PCM has the advantage, that a level 4 protocol would: not be needed to eliminate hard-to-u.nderstand gaps in the audio. With developement and a level 4 protocol for differential PCM. To eliminate the gaps, this might gain an additional audio channel and make all channels distortion free.

Conclusions

The Cellnet concept is the best way to proceed from this point in time onward for the development, and implementation of packet transport networks. It is .a no compromise solution to our biggest problem, and is also the system of maximum quality In metropolitan areas, point-to-point bypass links will be still be needed, but rural cellnets as described would have equivalent performance as rural terrestrial point-to-point up to 56 kBd.

There is significant development to be done to improve Cellnets' wide spread implimentation. Luckily, many of the packet projects of recent months are directly applicable to Cellnet systems, with small software changes. An RF hardware prototype is not assembled as of this writinq in August 1988. IMD may change the designs in figures 4 and 4a. Specific hardware that can probably be made into an assembled Cellnet site is identified, and we are about to begin purchases.

Packet clubs on average are meager affairs. With a few exceptions, packet clubs are not going to be able to fund a complete Cellnet over their memberships area. On the other hand there are many rich repeater and general interest ham clubs with lots of hamfest receipts sitting in their banks. Much of this goes to fund the next year's hamfest, but a lot sits and accumulates. Much worthy support for Cellnet can be had if some of the Cellnet thruput is applied as audio link channels.

References:

1) "Radio Propagation Fundamentals," Kenneth Bullington; Bell System Technical Journal, Volume XXXVI, #3, May.1957

2) Reference Data for Radio Engineers, 6th Edition, Copywrite 1977, Howard W. Sands & Co., Inc.

3) "Modifying the Hamtronics FM-5 for 9600 **bps** Packet Operation," Steve Goode, **K9NG;** Fourth ARRL Amateur Radio Computer Networking Conferance, March 1985, American Radio Relay League, Newington, CT, USA

4) "A 56 Kilobaud RF Modem," Dale A. Heatherington, **WA4DSY;** ARRL Amateur Radio 6th Computer Networking Conferance, Copywrite 1987, The American Radio Relay League, Inc., Newington, CT, USA

Appendix 1:

Local Oscillator Scheme for 1250 MHz
Cellular Packet Radio Network **(Cellnet)**

Here is a mixing scheme and local oscillator frequencies to do 1250 MHz **Cellnet** with 2 MHz bandwidth duplexer bands centered on 1250 MHz and 1299 MHz portions of the 23 cm amateur spectrum. This idea can be implemented with a L.M.W. model # UNLV02 circuit, with the addition of a X 2 tap and buffer amplifier. In the **Cellnet** concept, each site transmits on one duplex band, and receives on the other. Thus, neighboring stations to a particular site receive and transmit on the opposite duplex bands. Consequently, the mixing schemes below are bidirectional, with the indivdual sites using the appropriate transmit and receive bands, to suit the local network enviorment. This scheme is designed to use the maximum duplexer bandwidth available of typical **BP/BR (BandPass/BandReject)** cavity duplexer sets. A **BP/BR** cavity set helps provide protective filtering for the wide bandwidth converter circuits. The 2 MHz could be broken up into a variety of channelizations. Other investigations have shown that for a **Cellnet** system, 5 channels are required. Thus, the maximumn thruput scheme would be 5 by 400 Khz channels. Such bandwidth could support 200 **KBaud** data rate.

```
Low     25.0 --- X - 155.286 - X - 1249
Channel to 27.0  !   157.286   !   1251
                 !   BPF       1
91.143 -X2- 182.286 -X3-X2- 1093.714
L.O.   Chain     !             !
                 1             1
High    23.0 --- X - 204.286 - X - 1298
Channel to 25.0      206.286       1300
                     BPF
```

The **WA4DSY** modem/exciter should work with this scheme with a change or two in some coil values. This scheme could also work with **K9NG** modems and commercial versions of Hamtronics receiver and exciter circuit boards at the 156 and 205 frequencies, Both signal paths need to be highly shielded from each other and any RF equipment operating in the site's vicinity on the 1st IF frequencies. This would not be a **catastrophy** unless a local transmitter happened to coincide with one of the 3 receive channels within the particular site's **receive** IF. The channels are 80 KHz wide for the **WA4DSY** modem, and 20 KHz for the **K9NG** modem. With a metropolitan coverage net, as CAPRA is planning to use this scheme for, the site spacing is roughly 15 miles, so antenna heights only need be 30 feet above average terrain or tree clearing height, whichever is highest. Thus new sites should be easy to procure if one does not work out. The **IFs** of this scheme are outside the ham bands, thus this scheme allows full use of these for whatever other purposes at a particular site.

Appendix 2:

RF Equipment Specifications for 1250 MHz
Cellular Packet Radio Network **(Cellnet)**
Don Lemke - June, 1988

Fully Neighbored Site

Antenna:

* Larson # **FB3-1290** - Omni-directional, **9dBd** gain, Fiberglass radome, $120.00

***Cablewave # FLC78 - **7/8ths** Inch Dia. **Heliax (tm)** coaxial cable, 50 feet needed per site, $196.00 **($3.92/foot)**

***Cablewave # **NM78CC** male - N Male Coaxial Cable connector; $108.00 (2 @ $54 ea.)

Duplexer:

** **Tx/Rx** Systems # 28-97-010 - **12** MHz min. spacing, .9 **dB** loss, 200 KHz min. notch?, 2 MHz min. **bandpass @** 1.9 **dB** total loss $371.25

Radio system:

* L.W.M. Electronics LTD. # UNLV02 - Local **oscilator** system, **incl. xtal,** Freq = 1093.716 MHz $95.00

* L.W.M. Electronics LTD. # **1296PRM2** - Receive preamp and Mixer. $93.38

* L.W.M. Electronics LTD. # **1296TMA3** - Transmit Mixer and Amplifier, 1 watt output **power,** $127.46

** Pauldon Associates
#M57762 - 23 cm band power amplifier, 20 w. max, 18 w. for 1w. drive, MINUS heatsink, 7809 auxiliary bias regulator and connectors, $106.00

* Homebrew - T/R Second IF subsystem, LO driver, Rx splitter, parts for power amp, Estimated cost - $60

* Crystals - 3 receive, 1 transmit, $60.00

* Bud # CU 347 - Shielding Enclosure, Estimate 3 per site, $40.05 (3 @ $13.35)

Notes:

* Purchase these items first, this equipment required to start rf and computer development.
** Purchase these items after initial rf and computer development is done, Needed to develop full duplex mods to rf equipment, and test computer with duplex thruputs.
*** Final equipment purchases prior to installing equipment at a working site.

Vendors:

Larson:

Larson Electronics Inc.
11611 N.E. 50th Avenue
P.O. Box 1799
Vancouver,WA 98668

Cablewave:

Nemal Electronics Inc.
12240 NE 14th Avenue
N. Miami, FL 33161

TX/RX Systems:

TX/RX Systems
8625 Industrial Parkway
Angola, NY 14006

L.M.W. Electronics U.S.A distributor:

Down East Micorwave
Box 2310
RR 1
Troy, Maine 04987

Pauldon Associates:

Pauldon Associates, W2WHK
210 Utica St.
Tonawanda, NY 14150

Bud:

Many vendors thruout the U.S.A.

Estimated RF equipment cost: $1400.00

TABLE 1

Cellnet RF Margins

220 Mhz - 6 dBd antenna

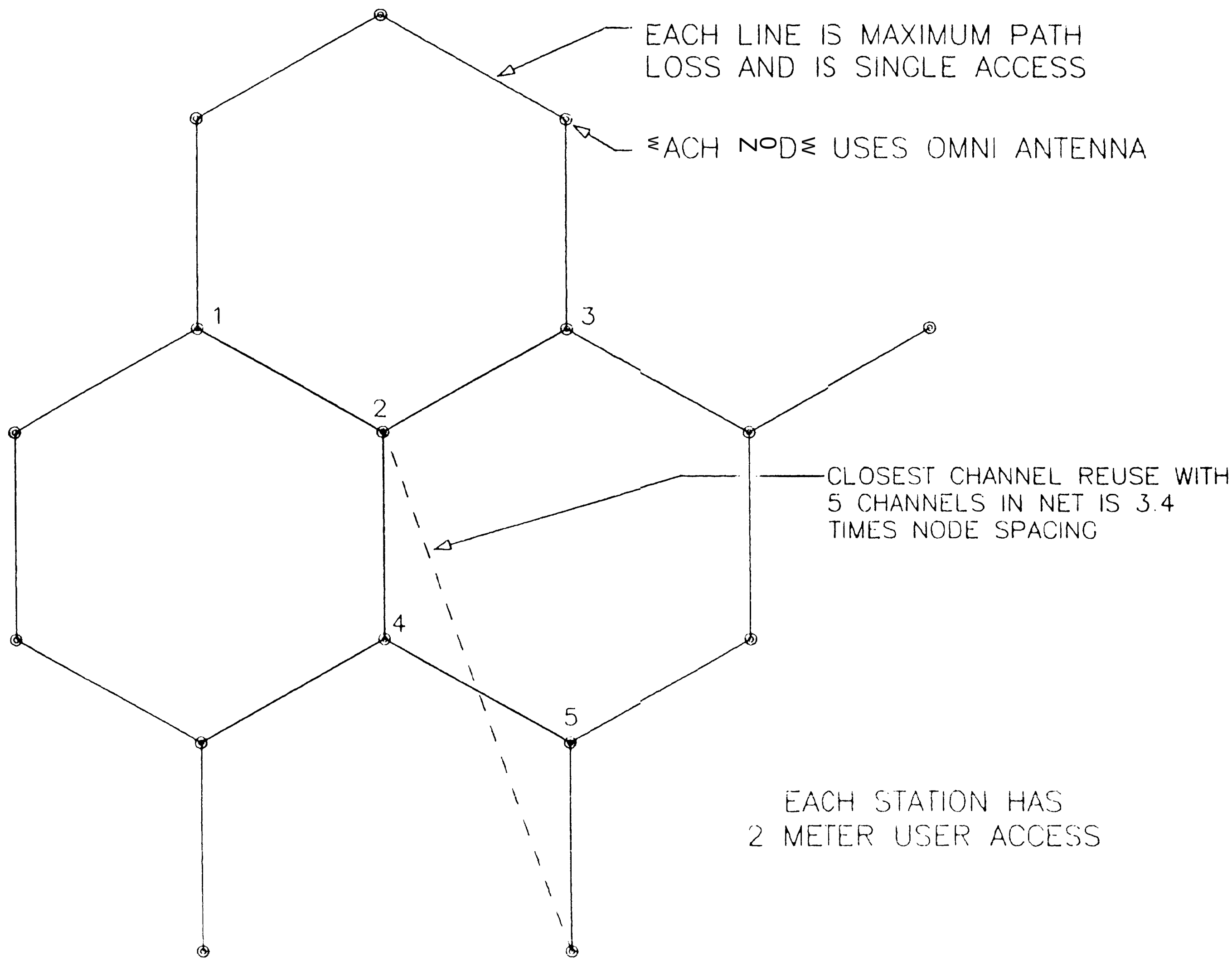
Distance (miles)	F.S.L. (dB)	Antenna Height (feet)	Cable loss (dB)	Fresnel loss (dB)	Total loss (dB)	Te (K)	Nrx (dBm)	RF power (dBm)
25	111.5	78	.70	22.8	138.7	10914	-109.2	46.3
30	113.0	113	90	21.3	139.1	10969	-109.2	46.7
35	114.4	153	i.i	19.8	139.4	11030	-109.2	47.0
40	115.5	200	1.4	18.8	140.1	11122	-109.2	47.7
45	116.6	253	1.7	17.9	140.9	11224	-109.1	48.6
50	117.5	312	2.0	17.1	141.6	11334	-109.0	49.4
60	119.1	450	2'8.	[illegible]	143.6	11662	-108.9	51.5

450 Mhz - 9 dBd antenna

Distance (miles)	F.S.L. (dB)	Antenna Height (feet)	Cable loss (dB)	Fresnel loss (dB)	Total loss (dB)	Te (K)	Nrx (dBm)	RF power (dBm)
25	117.7	78	1.0	20.8	143.5	4006	-113.5	40.8
30	119.2	113	1.3	19.2	144.0	4090	-113.5	41.3
35	120.6	153	1.6	18.1	144.9	4189	-113.4	42.3
40	121.7	200	2.0	17.1	145.8	4334	-113.2	43.4
45	122.8	253	2.4	16.3	146.9	4499	-113.0	45.7
50	123.7	312	2.9	15.5	148.0	4708	-113.4	46.0
60	125.3	450	4.0	14.2	150.5	5282	-112.3	49.0

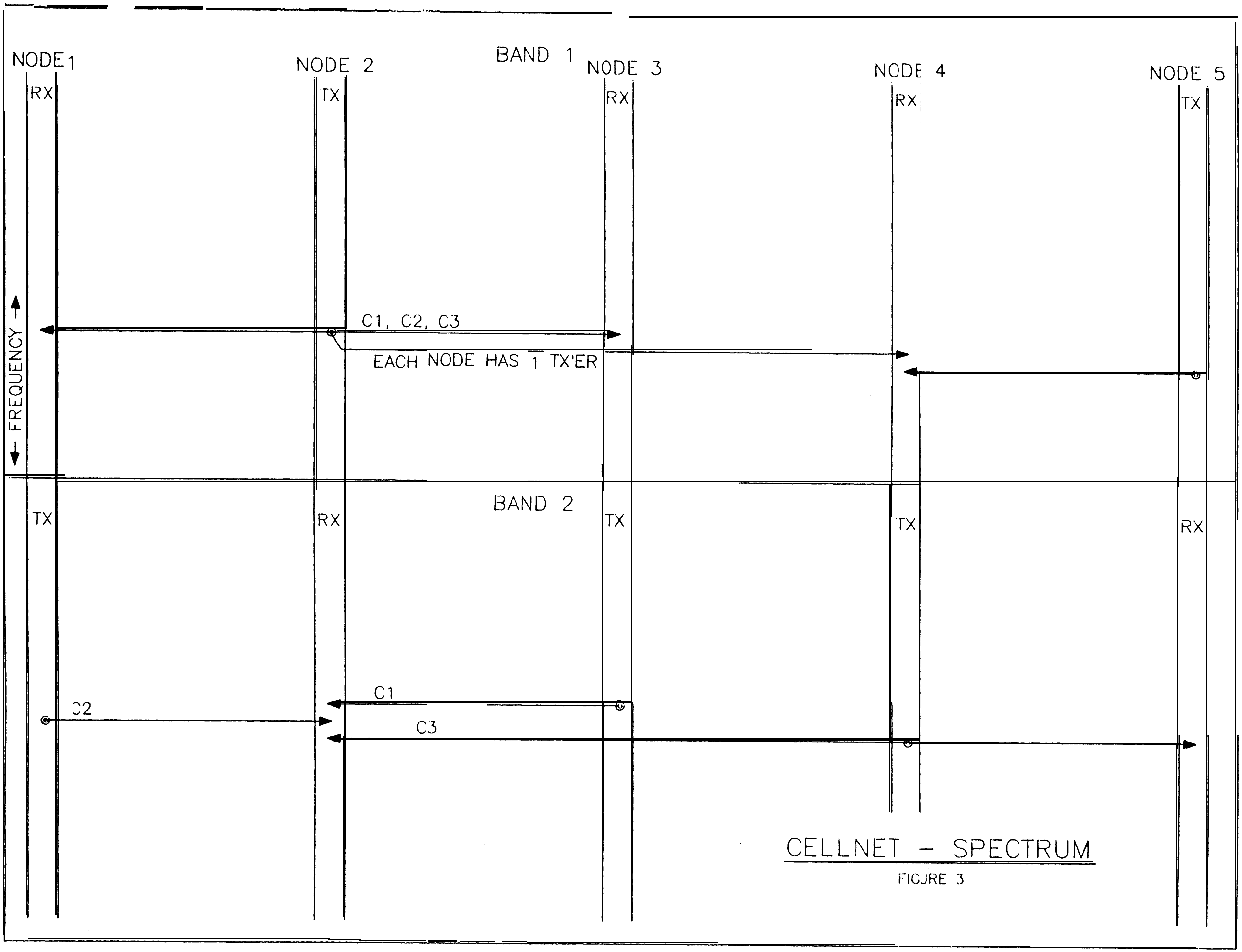
1250 Mhz - 9dBd antenna

Distance (miles)	F.S.L. (dB)	Antenna Height (feet)	Cable loss (dB)	Fresnel loss (dB)	Total loss (dB)	Te (K)	Nrx (dBm)	RF power (dBm)
20	124.9	50	1.5	19.7	150.6	1447	-118.0	43.4
r.t.			.75		149.1	1217	-118.7	41.2
15	122.4	28	1.1	22.0	149.6	1319	-118.4	42.0
r.t.			.75		148.9	1217	-118.7	41.0



CELLNET - AREA COVERAGE

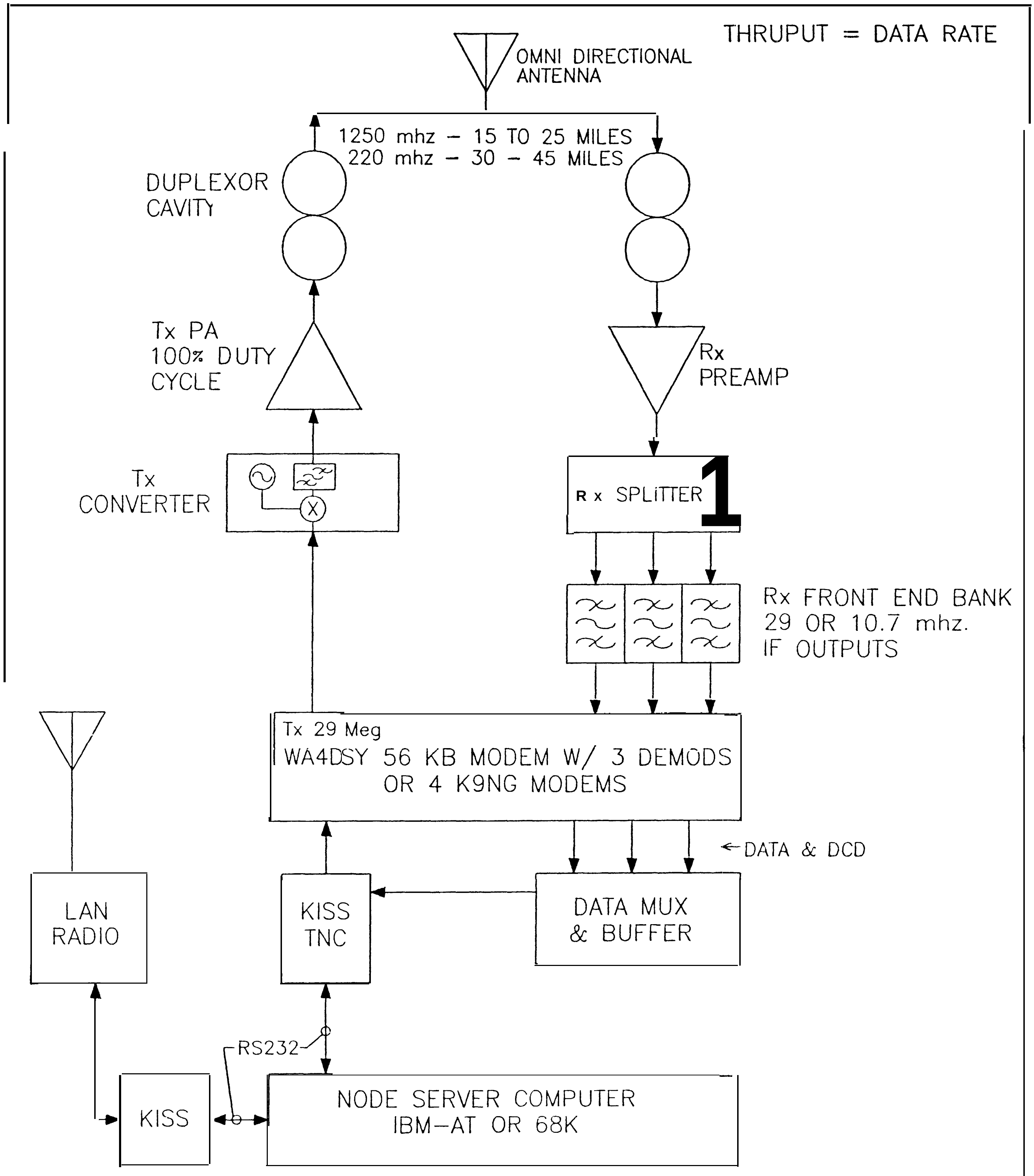
FIGURE 2



CELLNET - SPECTRUM

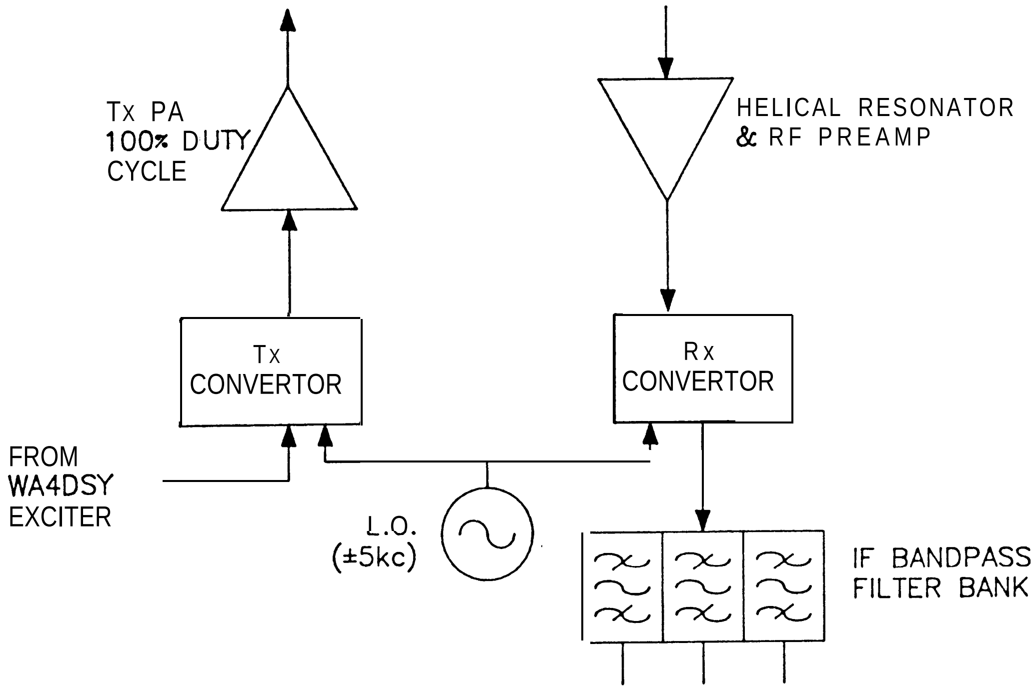
FIGURE 3

CAD REF. CELLNET6



CELLNET - FULL DUPLEX EQUIPMENT

FIGURE 4



CELLNET – **FULL DUPLEX**

ALTERNATIVE RF EQUIPMENT

FIGURE 4a