IEEE P802.11
Wireless LANs

Questions and Answers on Lucent /NTT OFDM proposal

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Introduction

This document reflects the question and concerns of people expressed with the Lucent Technologies/NTT proposal in Technical Group A of IEEE P802.11, and the answers and clarifications given by the proposers. This session was held Thursday, May 7, 1998, between 3.15 pm and 7.30 pm. (technical questions) and on Thursday, May 8, 1998, between 1.15 pm and 3.00 pm. (intellectual property question)

The document is structured as follows.

> **Questioner: Questioner's name**
> **Vote: Questioner's vote**
>
> *Question 1: ...*
>
> Optional clarification or elaboration of the question.
>
> Answer to question 1
>
> Comments to the question and the answers. Follow up questions, discussion, etcetera.
>
> *Question 2: ...*

and so on. Questions are listed in order in which they were received at the secretary's desk.

Questioner: Gene Miller
Vote: Was unable to attend ratification vote

Question 1: One of the desirable features of the single carrier OQPSK approach was the migration path to 50 Mbit/s data rates. How would the OFDM approach be modified accommodate migration to higher data rates?

Richard van Nee: Our proposal is amendable, and we are open to proposals to increase the bit rate. To do that we have the following options:

1. Adopt a higher bandwidth. In an earlier version of the proposal we proposed a basic rate was 33 Mbit/s, a high rate of 50 Mbit/s and a raw, uncoded bit rate of 60 Mbit/s. The downside of is that less than the current 11 channels will fit in the band.
2. Adopt the channel spacing as in the current proposal, but go to higher QAM levels. Going from 16-QAM to 32-QAM, the raw rate would be 50 Mbit/s, as for the OQPSK proposal. The only change in complexity is QAM mapping and demapping. The FFT part, which is the most difficult to change, remains the same. It does cost SNR. Existing OFDM systems such as ADSL and DVB are examples of systems that use higher level QAM. For instance DVB uses 64-QAM.

Gene Miller: Do you have performance analysis results?

Richard van Nee: Yes, see earlier (November) version of our proposal, with the 33/ 49.5/66 Mbit/s low/high/uncoded rates with 24 MHz channel spacing.

Gene Miller: I have to think about it, have to read the papers first.

Naftali Chayat: ADSL is not a good example, it works in a different environment. There is no phase noise since it is a baseband modulation method.

Richard van Nee: That is true. However DVB (Digital Video Broadcast) is wireless and has comparable parameters to our proposal. Bit rate is 30 Mbit/s after coding. The modulation scheme is 64-QAM. The same convolution code as in the Lucent/NTT proposal is used. The coding rate is 3/4 or 2/3. DVB also uses code puncturing to get different coding rates. The frequency band is UHF, so there is phase noise as well. It is a continuous time technique (as opposed to packet based transmission). But synchronization is actually more difficult since DVB assumes mobile users. In wireless LANs we do synchronization once per packet, in DVB synchronization is a continuous process. The number of carriers is 8000, so the carrier bandwidth is more than 100 times lower than for the Lucent/NTT proposal. So, the phase noise problem is an order of 100 more severe. DVB uses pilot symbols, (25% to 30% of all subcarriers), which is much more than for wireless LANs (where 3 out of 48 are used as pilots) since DVB must track the channel dynamically. The backoff is less of an issue as there is a centralized transmitter. DVB is designed for multipath tolerance on the order of microseconds. The guard time is even 200 microseconds, which is done to allow single frequency networks — in which all base stations can use the same frequency. The mobiles receive many copies of each symbol with time difference due to different propagation delay. These copies are dealt with just as with multipath echoes. The existence of DVB shows that you can use OFDM with a large number of carriers without phase noise problems. It also shows that multilevel QAM can operate in a harsh multipath environment. The hardware implementation is comparable. The FFT size is larger than required for wireless LANs, and synchronization is more difficult. Chips are available now, showing the technique is mature enough.

Questioner: Wes Brodsky
Vote: No

Question 1: Have spent so much time on TGb, have not had enough time to evaluate TGA backoff requirements. Hesitant to vote for OFDM since it seems the constant envelope property of OQPSK should make it superior. Don't understand requirements of U-UNII vs. Restricted regulations. Which holds; when and where. If it is uncertain which holds, which is the most likely to hold?

Don Jonhson: The restricted band requirements hold at the edges of the UNII band. Lucent measurements show compliance to restricted band requirements. The lower band has maximum power requirements and can be used indoors only.

Richard van Nee: For the restricted band requirements OFDM is 1dB better than OQPSK (it needs 1dB less backoff). The reason is that the single carrier spectrum shows a huge -57 dB bandwidth. The OFDM spectrum is much steeper, close to a rectangular (brick wall) shape in the ideal case (no PA distortion) but still very steep in the presence of PA distortion. This is in fact one of the advantages of OFDM. The backoff requirement is conflicting with a higher data rate both for OFDM and OQPSK. If you go higher in same bandwidth, you have to move to a higher level of amplitude modulation, and you need a backoff of 6dB.

Wes Brodsky: Comment from Naftali on that?

Naftali Chayat: Richard is right in stating that single carrier needs backoff as well. Still I think there is some advantage for specific channeling schemes that were shown, although the advantage is rather small. In real, the difference will be slightly higher. Cannot comment on numbers, my guess is another decibel, maybe two.

Question 2: Prefer OQPSK since it has more similarity with preferred TGB (2.4 GHz) waveforms.

Wes Brodsky: Design work the companies have done in 2.4 band would carry over to 5.2 GHz band for the base band.

Dean Kawaguchi: I have a similar comment. There is learning process, even though the IF section might be the same.

Bruce Tuch: The RF section will change radically anyway if you go from 2.4 to 5 GHz, independent of the type of modulation.

Wes Brodsky: I'm talking about baseband functions; in the Harris proposal for high speed in the 2.4GHz band, the Walsh functions are new, but the rest, the digital modulator, is the same as for the low speed modem.

Question 3: Prefer OQPSK (single carrier) since it supports migration to higher data rates than OFDM (50 vs. 30 Mb/s)

The answer to Gene Miller's question applies.

Reza Ahy: On the other hand, I would like to know how you can use an equalizer at 50 Mbit/s. Naftali, do you really believe in it.

Naftali Chayat: If I wouldn't believe in it, I wouldn't present it. There are examples in radio trunk systems, although there the delay spread is shorter than in our environment. They are 155 Mbit/s systems with 64 QAM modulation with a 20 GHz carrier frequency. However, this is more expensive equipment, which you can not put on a PCMCIA card.

Reza Ahy: What is the equalizer power consumption in a PCMCIA implementation?

Naftali Chayat: 300mA in a 0.25 micron ASIC implementation. This goal is aggressive now, difficult tomorrow, and history the day after tomorrow.

Tie-Jun Shan: I worked on a wireline ATM transceiver in 0.25 micron and designed the equalizer. The major power consumption was due to the equalizer.

Richard van Nee: The 50 Mbit/s quoted in the OQPSK proposal is the *raw* data rate, which is 40 Mbit/s for OFDM. Document 97-123 shows performance measures for OFDM using higher rates. They are not in the matrix, since after merging all proposals went to 20Mbit/s for reasons of comparison. Another reason to go to lower rates was not to scare off people. If the majority of this group wants to go to higher rates, we are completely open to that.

Naftali Chayat: I met people in the elevator today who say an equalizer at that rate is doable.

Bruce Tuch: They also said it costs 350 kgates, if I was in the same elevator as you were.

Questions: Greg Rawlins
Vote: not specified

Two sets of questions.

A. Concerns with OFDM

Question 1: Has Lucent addressed the issue of maintaining tone orthogonality in the real world scenario of real filters, non-linearity of amplifiers.

Greg Rawlins: I was involved in the development of an OFDM-like system. It started out as a pleasant experience and ended as unpleasant. In practice the system was very difficult. When we added RF and started to shrink the system's dimensions we experienced problems. These were solved in the end, but at an expense of extra power and complexity.

See answer to question 2.

Question 2: What is the sensitivity of OFDM to AM-PM

Answer (applies to both questions 1 and 2).

Richard van Nee: We actually measured the spectrum in magic wand. We observed that the PM distortion effect is secondary, the AM distortion is dominant according to Rapp's claims, and it is reflected in his model which we used in our simulations. We use 5dB backoff to get a sufficient BER. performance. In my 97-123 contribution you see the effect of clipping in a comparison between the system with an ideal amplifier and Rapps amplifier model. To meet the restricted band requirements for out of band radiation, you need a an additional 2 dB backoff, so 7dB in total. We did not look at spectral regrowth in the center of the spectrum (the null carrier, or DC carrier will start to fill up), the effect is included in the simulations.

About the effect of real filters; OFDM is not sensitive to filtering distortion at all, because sine waves remain orthogonal independent of any phase and amplitude differences between them.

Question 3. How do the various tracking and acquisition process behave in AWGN and multipath environment.

Greg Rawlins: In our system, we were doing joint estimation of AGC (Automatic Gain Control) and carrier offset.

Richard van Nee: We use a similar approach as in the 2.4 GHz receiver. In the preamble you learn timing and frequency offset and coherence phases of the carriers. The only parameter we correct *during* the packet is phase offset, due to local oscillator offset. All these effects are included in the simulation. Including acquisition.

Naftali Chayat: Our OQPSK results also include the acquisition, which was a requirement for the comparison matrix. Adaptation has an advantage. The equalizer initialization is not 100% accurate, since it is a) an algorithm involving a number iterations, so the initial tap coefficients can be slightly off b) you train on noisy data. As a result, the first bits may not be equalized perfectly but then equalizer starts to adapt and results improve. Adaptation of the equalizer can take care of timing drift, which can be thought of as a filter, which an equalizer can take care off. It remains a difficult problem to go from initialization mode to tracking mode. We did not simulate oscillator effects such as pulling.

Question 4: What is the AGC algorithm and how fast does it acquire? How sensitive is it?

Question addressed earlier.

Question 5: Has an NPR like analysis been conducted (wide band intermod)

Greg Rawlins: Internally generated spurious was a problem. You cannot simulate everything.

Richard van Nee: The effects of a nonlinear amplifier was taken into account in all simulations by using Rapp's PA model with 5 dB backoff relative to the saturation level.

Dean Kawaguchi: What is maximal rate of change of the phase drift.

Richard van Nee: I cannot give the exact figure here, I refer to the matrix.

Carl Andren: Did you address PAPR (Peak to Average Power Ratio) reduction?

Richard van Nee: In the Magic WAND project we reduced the worst case PAPR to 6dB. In November I presented this and some other methods you can use to reduce PAPR. We do not use the Magic WAND method here since this code has the problem that the coding rate goes down as the number of carriers increases (Magic WAND uses 16 carriers). Besides, we found out that you can clip OFDM signals at 5dB without noticeable effects on the BER, so we can live without a PAPR reduction method.

B: Concerns with OQPSK

Question 1: Can Breezecom implement fall back rates below 21 Mbit/s?

Naftali Chayat: We did not focus on that and do not have immediate results. It is something we did not check. I believe it is doable but we do not have data to present. It would involve having multiple error correcting codes for different rates. We did not think it was crucial for this forum.

Greg Rawlins: Did you consider rate scaling?

Naftali Chayat: This would affect spectrum and it is better to avoid it. Maybe some repetition code cane be used. We did not investigate that.

Greg Rawlins: Is Breezecom open to this?

If this would lead to reconsider our proposal I assume we would consider it.

2. Can you simulate acquisition and the process of going from acquisition to tracking (for both proposals)

Already addressed.

Questioner: Karl Hannestad
Vote: Yes

Question 1: Concerns:

- *Complexity of both Tx and Rx.*
- *Cost of implementation in both current and dollars of hardware + implementation IP*

This questions has been addressed earlier.

Questioner: Jim Baker
Vote: No

Question 1: I believe the OFDM wave form is an elegant solution. My concern is that the implementation is complex, will be difficult to anyone other than Lucent to implement in the near term and, therefore, combined with the intellectual property cost will be expensive for the market.

Dean Kawaguchi: We will hold off until the IP discussion comes up later.

Questioner: Kazuhiro Okanoue
Vote: No

Question 1: As a vender, we would like to have a flexibility to trade between receiver complexity and performance so that we can have a range of products, each of which is optimized for a specific environment.

Richard van Nee: We saw that the main difference in complexity between the OFDM and OQPSK proposals was caused by the FFT and the equalizer. The equalizer is a factor 8 more complex than the FFT. If you go from 8 taps to a single tap, you have something that is as complex as the OFDM system. However, we are not discussing the single carrier proposal here, which was voted down.

Question 2: Is it possible to have a low cost receiver that supports both 20Mbit/s with coherent detection and fallback mode with non-coherent detection?

Richard van Nee: Let's look at the difference between coherent and differential. In coherent you multiply reference phases with corresponding carriers. In differential detection you multiply the carrier with the previous symbol. From a complexity point of view: the difference between coherent and differential detection is minor compared to the FFT and the decoder.

Dean Kawaguchi: It seems that the non coherent mode would be more difficult at a frequency offset of 12 or even 40 ppm.

Richard van Nee: The frequency offset is removed in the beginning. This is done digitally just as in the single carrier proposal.

Question 3: What is A/D converter accuracy?

Eight bits were used in the Magic WAND demonstrator to get safety margin, where we have a weaker code than in this proposal. In Magic WAND we can bring the number of bits down to 6. For the Lucent/NTT proposal we can get down to 5 bits.

Questioner: Jim McDonald
Vote: No

Question 1: Clearly OFDM is a powerful tool to be used to avoid severe ISI distortion problems. The question I have is whether or not the in-building WLAN environment will have sufficient level of ISI to justify the cost and risk. It is becoming more and more apparent that sectored/directional antennas will be required to achieve range and coverage at 20 Mb/s at 5 GHz which is reasonably comparable to 802.11 systems with 1 Mb/s at 2.4 GHz. Given that there is at least modest utilization of directional antennas, the delay spread will be less than what has been measured with omni-directional antennas. The single carrier approach allows the option of simple to rather complex radios to meet the supplier's expectation of need vs. cost goals. With OFDM there is a serious step function that be accepted even if the power of OFDM is not needed. There is also a question of risk, especially associated with small portable hardware associated with OFDM.

Jim McDonald: Comparing bit rates: from 1 Mbit/s to 20 Mbit/ represents a 13 dB step. From 2.4GHz to 5.2 GHZ, is another 6 or 7 dB difference. In total there is a 20dB gap, with users expecting similar coverage range. Directional antennas can compensate about 20 dB, so you an have comparable coverage area, while delay spread is going down. In the last ETSI BRAN meeting, Ericsson has result of links with directional antennas at one end. Product with Simple equalizers or even without equalizer may get away. The result is a simpler radio structure. I am a bit confused by answer by cost reduction which might be associated by using a simple implementation, which could actually be done by an amplitude limiting receiver. Single carrier allows for a range of implementation which can be cheap, or better and expensive.

Bruce Tuch: What will make you vote yes?

Reza Ahy: We believe that an equalizer is not scaleable. It is highly non-scaleable. The complexity is severe.

Jim McDonald: To repeat, we a re concerned with AGC, VCO transient function, and Cost factor. Different data rates may be a problem.

Questioner: Dean Kawaguchi
Vote: No

Question 1: I would prefer single carrier because of its similarity to all 2.4 GHz proposals.

Question addressed earlier.

Question 2: I believe the PA backoff needs to be more than 5 dB. Previous papers by Lucent showed only reaching 5 dB with peak to average reduction.

Question addressed earlier.

Question 3: How was the carrier offset of 40 ppm (200 kHz) with sub-carrier spacing of 250 kHz achieved?

Question addressed earlier.

Question 4: I am concerned by the IP position of this proposal.

- *The distributed statement by Lucent does not say "all applicable patents mandatory and useful for implementation" and also specifies 5% of the product.*
- *While Bruce Tuch has verbally clarified that it will be limited to the ASIC, the written statement does not. 5% of our "product" would be extremely unacceptable.*
- *The OQM proposal was less likely to contain IP that would require licensing fee, either mandatory or implementation effectiveness.*

Lucent dominance at both 2.4 GHz HS and 5GHz in US, Europe, and Japan would be bad without full clarification of IP position in (3). I would change my vote if the IP were all offered at $0 charge.

Reza Ahy: The IP issue affects many peoples' votes. Can you describe what the patents describe.

Bruce Tuch: The *technology* license is 5%. The IP license is much, much less. I will get back on this issue.

Questioner: Jim Zyren
Vote: No

Question 1: I voted no because the IP position is unclear. I am strongly in favor of making every reasonable effort to adopt a solution which has no mandatory I.P. attached. At a minimum, the IP position must be made clear so that potential users will be able to make an accurate determination of the associated costs. Specifically:

Question 1: Clarify fees & royalties. Provide itemized schedule of fees:

i. License for issued and pending patents essential to the practice of the referenced standard

ii. SPW block diagrams

iii. Design notes

iv. 20 hours of consulting services

Bruce Tuch: We copied the technology license statement which was written for our 2.4 GHz proposal, and changed "2.4" to "5.2". However, I know of no patent which is essential to implementation of the 5.2 GHz standard. I am not in the position to say that Lucent Technologies has no patents which are essential to implementation of the standard. If there are, then we follow the "reasonable, fair and non-discriminatory fee" statement of the IEEE. As an individual, I cannot state non-enforcement of patents.

Question 2: Lucent stated that there is no IP on the waveform. Can this be put in writing as a submission?

See answer to question 5.

Question 3: If there is no IP on the waveform, what is the IP "essential to the practice of the referenced standard?"

See answer to question 5.

Question 4: Does Lucent or anyone else in TGa know of IP (including that of a third party) which is attached to the 5 GHz proposal?

See answer to question 5.

Question 5: Please specify the point of application for IP licensing statement (Chip? Radio? Product?)

Bruce Tuch: What IP is essential and what the point of application is an academic point, as I have no knowledge of patents which apply to the implementation of the standard.

Vic Hayes: Even if Bruce sends me a letter stating he has no knowledge of patents which apply, I will not accept it. I will only accept a letter from an officer of the company.

John Fakatselis: We can not force Bruce into stating this. It is fair to ask the sponsoring company to answer the IP concerns that we may have and let Bruce off the hook.

Dean Kawaguchi: The purpose of this session was to give feedback to group members. Concern that I have is about the 5% in the IP statement.

Petri Jarske: I am not familiar with all rules of this forum. Personally I think this discussion is out of proportion. Should we ask all the other companies present here as well if they have applicable patents?

Jim Zyren: Zero licensing would takes away the concern.

Dean Kawaguchi: I will cut off this discussion. We can not allow any coercion by the group.

Al Petrick: You don't want to put forward a standard by a company which has IP on it.

Keith Amundsen: Is our task to ask one or require an IP statement. The "reasonable, fair and non-discriminatory fee" statement is what we have and I think it is not detailed enough.

???: This should be a point for every 802 meeting. Let's read the bylaws.

Johnny Zweig: What I think Bruce said is that Lucent has a lot of patents on a lot of issues but has none that he's aware of which applies to implementation of this standard. If we choose a different standard, there may be patents on it, in Lucent and in other companies as well. The bylaws are there to protect us against doing the work to find this all out. One way a proposal could be sweetened is by saying "I have patents and you're getting them for free." We are getting in the range of having an impractical and protracting discussion which is not going to lead us anywhere.

Naftali Chayat: I feel that we cannot prevent everything. I feel that Lucent gave an IP statement that it will provide IP on a "reasonable, fair and non-discriminatory fee" basis. I can design an OFDM system, put it in a box and it would be impossible to detect IP infringements. We have basis to move on and should not get stalled. If companies need external assistance with the implementation they should pay for that as for any other consultant service.

Bruce Tuch: The technology licensing letter is not relevant to this meeting

Anil Sanwalka: If we could get a letter of an officer of the company that says what Bruce is saying then the issue would be solved.

Questioner: Naftali Chayat
Vote: Abstain

Question 1: There are broadcasting standards using OFDM (DAB, DTV), but no mobile or even stationary (e.g. WLL) equipment with OFDM. Why? Phase noise? Backoff? Technology gaps? Fear of the new?

Richard van Nee: Since we are start standardizing it only now. Broadcast people started standardizing earlier, and recognized the problems and their solutions earlier.

Question 2: Why did HiperLAN (ETSI's 5.2 GHz, 23 Mbit/s wireless LAN standard) not choose OFDM.

Richard van Nee: In HiperLAN the main problem related to OFDM was backoff. The issues were not well understood at that time.

Simon Black: I attended those meetings. There was a lot of worry in the implementation complexity of the transmitter, in particular PA linearity and power consumption. Many people did not believe you could make an OFDM transmitter in a PCMCIA card. On the receiver side it is not a problem, and for broadcast this is where the consumer side is. However, it was a close decision in HiperLAN.

Question 3: The adaptation to the channel is performed over 2 symbols. That produces very little statistics and degrades performance. Is there any adaptation algorithm to improve the channel estimate, and how much does it contribute?

Richard van Nee: You are talking about SNR loss on channel estimation from the training overhead. You have to learn phases and amplitudes of all carriers. You do this by averaging over 2 training symbols. The estimates are not perfect because of noise. If you use just one training symbol instead of 2, you would lose 3dB. If you have an OFDM symbol with 48 carriers the amplitudes and phases are heavily correlated. By averaging over two adjacent subcarriers to find the phase and amplitude, you improve the channel estimates SNR by 3dB. In the simulations we implemented this.

Question 4: There is a need for timing tracking? For 40 ppm crystals, 12000 bit packet (2400 ms · 40 ppm = 96 ns). How will you handle it?

There are two methods. The easiest is to use the carrier offset to correct the clock offset, which is possible if carrier and symbol clock are derived from the same reference. This technique was also proposed in some of the 2.4 GHz TGb proposals. Another technique is to use a correlator over every symbol, since part of the symbol is repeated in the cyclic prefix. This technique was described by NTT in the November meeting last year.

Hitoshi Takanashi: A crystal precision of 80 ppm is also tolerable ($2 \times 96 = 192$ ns). We did simulations with that. If you use a 40 ppm (96 ns) it is much easier.

Question 5: For 40 ppm crystals the worst case frequency offset is 200 kHz on each side. How will you handle it. Does it impact DC leakage in receiver?

Richard van Nee: The easy answer is: we designed the systems for the highest possible frequency offset. With 10 ppm it would be easier. This problem also occurs in current systems. Solutions exist. You could measure the DC offset during training and subtract it.

Hitoshi Takanashi: 12.5 ppm errors (to both sides) can be tolerated. There is some degradation if it is more. If we can make the circuit ideal there is no DC leakage. The performance impact is of DC offset is the same as shown in our CW interference simulations. This effect can also occur in single carrier systems.

Question 6: What problems did Lucent experience during implementation of the Magic WAND project. Oscillator quality? Oscillator pulling, transients? Carrier leakage? What was the oscillator accuracy? How will those problems scale when going from 16 to 64 FFT size?

The WAND project is not completed. We did do RF measurements. Measurement with 4dB backoff showed a good match with the simulated spectrum using Rapp's model. Rapp claims that the amplitude distortion is heavier than phase distortion. This corresponds with what we see in the measurements.

Clipping of an OFDM signal causes out of band radiation. If you increase the number of OFDM carriers, the worst case PAP ratio goes up to. However, the amount of energy above 4dB, which you will clip and which will show up as out of band radiation does not change when you increase the number of carriers. If the number of carriers larger than 16, then since each OFDM symbol has a Gaussian distribution (it is the sum of a large number of sinusoids a random phase) the fraction of samples exceeding 4dB is the same. We also tested -57 dB bandwidth. We did comply to restricted band requirements at 8dB of backoff with the particular amplifier we used in the measurements, which is a commercially available M/A-COM power amplifier.

We cope with oscillator pulling. The phase of all subcarrier can change wildly over the symbols in a packet. If the change between 2 consecutive symbols is small (less than 15 degrees), we can cope with oscillator offset, since we use some of the carriers as a pilot to measure and compensate phase drift.

Jim McDonald: The VCO is going to have a steep MHz/mV slope. Implementation in PCMCIA form factor is a big concern. Once we nail it down, solutions can be found. At this moment in time we could have enormous requirements.

Richard van Nee: The problem with transients is that you lose your coherence. It is related to the phase noise problem, which is not specific to OFDM, it is the same for a single carrier solution.

Carl Andren: What is the A/D converter accuracy

Richard van Nee: You can get down to 5 bits A/D converters without experiencing SNR loss.

At 4 bits you starts to see SNR loss, at 2 bits the system breaks down. The reason that you do not need large dynamic range, since weak channels do not contribute to the result of the code. In fact, the A/D converter effectively erases weak carriers, which yields a better decoding result.

Richard van Nee: In a typical channel, of all carriers, 10 to 20% is significantly lower in amplitude than the rest.

Carl Andren: What is the sample rate?

Richard van Nee: We sample at 16 MHz: taking complex samples.

Jim McDonald: One of the "oh my gods" is AGC. It is a serious concern. AGC is not going to be perfect. There will be noise effects (perhaps radar) which is going to affect AGC design. Difficult to get to grips with AGC situation. In order to make linear schemes work, you may need digitally controlled AGC. The AGC and ADC is bucket full of worms.

Richard van Nee: This is not a critical issue specific to this proposal. Single carrier has the same requirements. The RF receiver is the same. We assumed in the proposal that we have 3 microseconds for AGC, which may seem quite short. Our RF people said that this was achievable. However, the AGC interval is debatable, it is not critical for us.

Naftali Chayat: In some of the simulations you had results for the lower rate incoherently decoded mode which was worse than in the high-rate coherent mode. Would you retain the

incoherent mode in the final mode or it just to keep NTT happy who proposed the incoherent mode.

Richard van Nee: These options are open to discussion. If the mandatory speed is not 20 but 15 Mbit/s, the case of differential detection would be simpler.

Naftali Chayat: I can not see how it helps. It can become more sensitive instead of more robust.

Hitoshi Takanashi: At this point the differential decoding cannot be removed. This issue should be addressed after the selection of the proposal.

Richard van Nee: I did simulations for 15 and 10 Mbps with coherent modulation, and I got the expected gain in SNR. You can use differential detection as an option, it is not a big issue.

Questioner: Keith Amundsen
Vote: No

Question 1: Would like to see higher data rate and clear IP statement.

First part of the question has been addressed earlier.

Second part of the question to be addressed later.

Questioner: Jeff Abramowitz
Vote: ?

Question 1: Cost concerns. Make a comparative advantage argument that justifies increased cost of product (including license fee) for OFDM vs. OQM.

Bruce Tuch: The comparison matrix shows gate counts.

Jeff Abramowitz: Relative to the total cost, what is the IP cost?

Bruce Tuch: I am not aware of applicable patents, what else can I say.

Question 2: IP Concerns. Using your system block diagram, show which elements contain IP protection.

Jeff Abramowitz: Does the stated Lucent IP protection describe an implementation(s) that must be used to meet their proposed standard? What is the "product" that the royalty arrangement refers to?

Bruce Tuch: This question is also IP related. I will study it in between this meeting and next.

Jeff Abramowitz: Your letter stated IP.

Bruce Tuch: This is technology license. I wrote these letters to make people comfortable.

Jeff Abramowitz: There were 3 patents.

Bruce Tuch: These patents are *not* in the standard. For instance crest factor reduction, we decided not to put it in the standard proposal. If there was ever a patent that referred to the point of application of the chip, and you apply this chip in a product, for example a scanner, then the "reasonable, fair and non-discriminatory fee statement" would not apply to the whole scanner. Sometimes you need to do tricks to get an implementation that is practical. There is plenty of opportunity in this proposal for everyone to be smart an get patents for themselves.

Darwin Engwer: In the precise wording of Bruce's statement the word "essential" is important. It feels to me that there is stuff that is not essential but which is necessary.

Bruce Tuch: There is no patent that you need to implement this proposal.

Greg Rawlins: Are you saying that you cannot commit your company?

Bruce Tuch: The technology license letter is causing confusion, we should get rid of it. We have no essential patents that we are aware of. Non essential does not mean we have no patents related to OFDM. We are not aware of patents related to efficient implementation.