John, please make corrections.
Henry

Interview: Dr. Kosmahl

I = Interviewer K = Dr. Kosmahl

I. We have with us today, Dr. Henry Kosmahl, who won 1986 NASA Inventor of the year title for his invention Linearized Traveling Wave Amplifier with Hard Linear characteristics. That's quite a long name for this, but it's very significant. Dr. Kosmahl is originally from Germany, now retired from NASA. He continues to be active in his work. First of all, what is a "traveling wave tube"?

K. Well, a traveling wave tube is an amplifier of very high radio frequencies that are being used in very many numerous applications such as space communications, ground communications, also in electronic Countermeasures, in radar operations.

I. When you're talking about an amplifier, is the amplifier similar to an amplifier you might have at home for your hi-fi?

K. Ah, no. The home amplifiers are low frequency amplifier and the traveling wave amplifier would not be very useful to them. It is most useful for wide band work, very high frequency application.

I. Now, these are used in satellites. What usually happens with a communications satellite? I mean, you have a signal coming up and another coming down. How does this amplifier traveling wave tube fit into the system?

K. Well, for instance, the best known communications satellites such as operated by Bell Telephone and other institutions of this type for tele-communications, for telephone conversations across the ocean, for transmission of other data and signals, like Olympic Games, and such a satellite usually carries more than 200 traveling wave amplifiers and because of the high band ~~vent~~width they can handle thousands simultaneously of conversations or operations at the same time.

I. So what happens with this amplifier if you have a weak signal coming in?

K. Right. The weak signal comes from the ground in a so called "up ~~bet~~ link", then received by the satellite. Now, the traveling wave amplifiers amplify the signal by a factor of 10,000 roughly, and then this is beamed down to receiving stations on the ground--this amplified signal.

I. Why do you actually have to amplify the signal? Why don't you just use it the way it is?

K. Well, it would be far to expensive and very wasteful to produce the monstrous amplifiers and to make the power on the ground because it would be dissipated too easily. It has a large width beam so the energy would be spread uselessly. And so it is beamed to the satellite with little effort at the low power level inexpensively, then amplified also relatively inexpensively by a factor of 10,000 and most of the amplifiers in space have a power level, typically speaking, of from 5 watts to 200 watts.

I. Now, I suppose we see all these home dish antennas these days, the amplifications is also needed so you can have a smaller antenna?

K. Right. Because of the very high frequencies, for instances, the dishes are usually operated in a so called "KU" band which is a frequency of around 12 gigahertz. And this requires a small dish because the wave length is small, consequently this can be handled with a small dish.

I. Now, let's turn to your own invention. Your invention uses what you call, I guess, a dynamic velocity taper - or DVT -- in the amplifier. What is this dynamic velocity taper or DVT?

K. The dynamic velocity taper is a crucial element in the subject invention and it fulfills a number of very useful services and does it very inexpensively. In other words, it is added to the existing amplifier just by minute changes which have, however, very significant consequences at the same time. But are inexpensively added to this. The functions which are produced by this dynamic taper, in principle, to the efficiency of the amplification process which is increased by roughly one third (30% -- between 25% and 40%). Secondly, it is very useful and desirable to have an amplifier being a linear amplifier. By saying, linear, it means that if the input signal is increased by a factor of 2, the output signal is also increased by a factor of 2 exactly, or 3 and 3. ~~At no place is 3~~ and the other ~~one grows by a factor of 4 or 2 1/2~~. So the amplifier is much more linear than the previous amplifiers which has very significant importance on the inexpensive consequences of processing a multitude of signals because linear signals can be processed by an amplifier without interference with each other. Therefore you can process more signals, there will be less interference and much higher quality of the signals. So this is the second element.

The third element is that this amplifier has a very small, what we call, phase face shift. Perhaps the best description for laymen of this would be that signals of different frequencies, for instances like a tenor and a base, they are amplified equally and without one being emphasized over the other. And finally, a very important characteristic is that this particular dynamic velocity ~~lift of the~~ taper produces a hard limiting effect. That means that once the amplifier approaches saturation, which means the maximum level it can put out power, this level stays constant over wide range of input power signals and so the undesirable signals are clipped off and this is very important in many applications such as in the Milstar ~~Noark~~ satellite.

I. Maybe what we ought to do at this point is draw a couple of pictures -- and we can stop the thing (tape). Because I think that maybe what we want to do is show the spiral and maybe what you can do is think in terms of saying, well, it's like a tube and we have a spiral staircase (if you want to compare it to a spiral staircase) or a slinky or a spring of some kind where the radio signals goes down the spring and the electrons fly through the middle and as they fly through they slow down and energy goes from the electons into the spring and the signal and makes it stronger as it gets to the end of the spring. If you can do that we can have some art work drawn up to coincide with what you are saying. So, could you try to explain it that way?

K. Yes. You put it very correctly. The central element of this traveling wave amplifier is the helix which is a spring like arrangement of wire of sort with very many, very tight turns. Now, what happens in the amplification process is this: the unamplified signal, the weak signal, travels with a speed of light around the loops of the wires--staircase or what you called spring. And the electron stream moves through the center, the opening, in the middle of the spring -- or helix. Now, what happens, the electons transfer the energy of motion into electro magnetic energy that moves along the wire and in the process of doing this, the electrons are slowed down at one point, and so the wave is much faster and begins to run away from the electrons. And the regretful thing is that at that time, the electrons still do have very sufficient energy which will be wasted otherwise. Now, the dynamic velocity taper, what it does, it tries to match the speed of the wave on the wire to the presently available speed of the electrons and the computer code shows how much it should be. And consequently, these two motions are linearized and synchronized and the rate of exchange of energy is much more intensified and the electrons do not run out of step with the slow down the way others being slowed down exactly at the amount which is best for the amplification process.

I. The spring, it is "squished" in or is it actually like the tip of a pencil tapered in that way at the end, so that it takes the wave a lot further as it gets to the end and takes longer to get there?

K. That is what we call the spacing between the wires and so on becomes smaller and smaller so the terms are tighter and tighter as you come to the end. And this is what we call an exponential taper. With the exponential taper essentially in the devices which have been built so far--and quite a few have been--this amounts to only 10% and it requires highly precise machinery like laser and computer controlled machines to wind this to a great precision. A precision for instance of 10 parts in a million. This can be handled very well with modern tools and because this change in pitch becomes 10% of the end, it initially is much less than 10%, it perhaps may use a fraction of a percent, and this could not have been handled, say, twenty years ago prior to the availability of this very sophisticated production tools. But now it works very well and it can be programmed and run automatically and they do with many of them, and these devices, as I said, are very efficient, really they are, and have this hard limiting characteristic and one thing I would like to point out--that contrary to public opinion, they are much more efficient then competitive solid state devices and ~~those are~~ much more linear. Devices like that, for instance, proved their ability to perform in NASA applications in deep space, for instances, on the Voyagers, Pioneer satellites that are now several billion miles away from the earth and more than ten years in space and they still function perfectly.

I. Earlier, before this interview, you have a very good description of the electrons traveling up a hill as if they were a convoy of trucks and they're slowing down going up the hill and there are red lights, you know, green/red lights, as it goes up the hill. Could you go through that description for me?

K. Right. This is a useful analogy for an observer who is not, perhaps, skilled in this particular field of science and the slowing down, what we wish is to synchronize the electrons as they move with the wave as it travels on this spiral. Now, this can be compared as you put it very correctly, with a convoy of trucks...

I. Could you stop just a second here. You may want to not refer to me because they will probably cut me out of much of the interview, so you might want to just pause a little bit -- a couple of second -- and just start over and just say "we could compare to a convoy of trucks...".

K. Then I shouldn't refer to you?

I. You don't have to -- just try not to.

(third voice) Just as if you are explaining it to him for the first time.

I. Right.

K. Well, this process can be described very well for those who are not particularly skilled in this field of science with a movement....

I. Let's stop once again.

K. This process of synchronizing the energy and speed of the electrons with the speed of the wave can be perhaps very nicely described, compared to the uphill movement of a convoy of trucks, heavily loaded, with a number of gates having green and red lights. What we would like to achieve is the trucks move up and they naturally begin slowing down. If the lights are synchronized to a constant speed, obviously, the trucks arriving at the red lights will have to make frequent stops and the whole thing will become chaotic. However, if the controlling device that controls the speed of the green light is synchronized and knows in advance what the speed and how much the slowing of the trucks will be, this can be very well synchronized such that when the trucks arrive at the top of the hill they will be still syncrhonized with the green wave and will pass without waiting for the red light. That is what is being accomplished here. And the computer can do it very well.

(DISCUSSION HELD FOR A MOMENT DURING VIDEO TAPE CHANGE)

I. I think what we'll do for the next thing is we'll go back... The dynamic velocity taper or DVT which is your invention increases the ~~velocity~~ efficiency by about a third from what you tell me. Now, what does that mean as far as power output of the satellite and what does it mean for satellite communications in efficiency?

I. Well, essentially, it reduces by a third the operational cost of a satellite. The power in space is such a premium expense it is important to make all the devices as efficient as possible. Now, increasing efficiency by a factor of third could be utilized this way -- that you operate and process a third more signals, telephone communications, radio communications at the same expense with the same satellite or you could make the satellite somewhat smaller by a third and still process the same amount of information as before.

I. Another advantage of the DVT or dynamic velocity taper is this linearity that results which means, as you put it before, that as you increase the energy for amplification going in, the electrical energy, your output goes up relatively the same amount. I guess that's what you're saying. Could you explain how and why that's important for computer communications linearity?

K. Well, linearity is very important for processing of a multitude of signals which is happening, of course, in a satellite, because in a satellite we have, I mean, thousands of telephone conversations, for instance, a lot of operations going on at the same time. In order not to interfere with each other, the process has to be linear and there are several phases of process to it and one is the power level is linear. That is, if you increase the input by a factor of 2, the output also increases by a factor of 2. The other aspect, also very important, is that what we call a phase. And a phase would be a time of arrival. The time of arrival of the various signals is also represented through situation of the original source--be it telephone conversation or music program, etc. and all this leads to discussions which limit the number of operations or require that you reduce the power -- not utilize the full power -- and reduces the number of channels. The process is not identically the same as in acoustics but perhaps the phase discussions which are very important could be preferred to a situation that, let's say on a stage in a music program the bases are heard earlier or later than the high-pitched instruments. Which, of course, is not the case if you are linear but it may happen in your amplifier.

I. Now, you also have computer information that goes up and down by satellite. I guess it's being used quite a bit for that.

K. Yes.

I. What if, you know, you are sending information up from the computer and it goes to the satellite and some of it doesn't arrive at the right time?

K. Well, if the computer operation is either the analogue information signal or digital signal. Everything can be expressed in terms of.. zero and one.

I. If you could compare it to what somebody at home could understand.. somehow...

K. Well, I don't know exactly...

I. What about computer information which is also transmitted by satellite sometimes. How do phasing problems and non-linearity that you described comparing it to music, how do these affect computer data?

K. Oh, yes. They do it very much. The deviation from one linearity of phase instructions cause errors in the number of received bits. Which is the digital form of data pulse transport. If there are too many errors then, again, the original information cannot be reconstructed.

I. So, what does that do to somebody's computer program or information?

K. Well, some of the data may not be usable. So it has to be--you have to limit the number of bits in at a time, which, again, I mean, is a question of economy. You would like to utilize it to a maximum degree and if it cuts down on the speed of information transmission--you loose.

I. People at home might know they have a home computer that may operate at 300 baud on a telephone line. Does that mean that you could operate with higher, what they call, baud rates if that's comparable?

K. Yes. They certainly could. Yes. Of course, it depends on if the telephone cable can handle this. In a satellite is much more. Modern satellites that operate on a digital principle of coding and decoding information can handle much more.

I. So the dynamic velocity taper, the DVT, it makes the.....

K. Error ~~depth~~ data ratio much smaller--much smaller so it permits you to transfer more data. Rate of data transfer is much higher.

I. How does that effect cost?

K. Well, the cost...I mean, if you operate much more, like how much money goes through -- speed of circulation and much more can be related to profit. Profit directly.

I. The dynamic velocity taper, the DVT, how close to the ideal amplifier is this device?

K. Well, the device comes very close to the ideal situation that the power output versus power input curve would rise as a straight line from the origin and move sharply and have put a dent into a horizontal limiting level that stretches over a large part of the input power level. There are some deviations from this ideal characteristics, but they are much smaller than in the previous amplifiers. And this has proved to be very crucial for the gigantic Air Force Milstar ~~NESDA~~ satellite that permit the Air Force to operate instant communications from any point on earth to any other point on earth. And this traveling amplifier will be a crucial point in this.

I. I jumped on you a little bit. The DVT then is ... what part does this play in this Millstar program. How important really is it?

K. Well, the DVT is a part of a traveling wave tube that processes the signals because after all the Millstar is an Air Force military communications satellite and very sophisticated, and to some degree classified. In other words they can handle secret signals and mix it and probably have some assurances against jamming, etc. So I do not know exactly because I am not involved in that part of the operation but it is required that the traveling wave amplifier that is the heart of the system that processes the information be a hard limiter. And that is what the DVT is doing to the amplifier. So DVT are inherent part of this and, as I said before, the important thing is that it is done incorporating inexpensively. It is a very smart and very simple and very inexpensive device.

I. Why is DVT important for modern radar systems too?

K. Yes. Everybody want a modern radar system. We have modern radars now that perform many functions at the same time. For instance, you can listen and you can also transmit at the same time. And those modern radars, especially in military applications, they operate over a large band width in contrast to other radars that have only a narrow frequency range. And wherever you have a large band width, you have a problem of linearities and distortion resulting from this. Now DVT give them much higher power and this is important if you talk about high amounts of power. I mean this is for instance like many of these devices operate~~d~~ at kilowatt, 10 kilowatt and more power level. And this energy simply went into heat and on planes it's also at a premium.

I. So, really what the DVT means is that you are close to the ideal and you can improve many forms of communications?

K. Definitely. Yes.

Short discussion about time and topics in interview, length of tape, etc. I.

I. (speaking to a third person) We are going to go on to some other inventions. I was just going over the questions I had written down and he has answered quite a few of them.

I. Is DVT being used in commercial communication satellites yet?

K. Very much. It has been used actually before it was published and presented publicly to the public. Hughes ~~You's~~ came up with several KU band traveling wave amplifiers with DVT '84 before the device was published.

I. Now, we've just talked about the KU band, I want to deviate a little bit here. I'm wondering if you could compare, like UHF TV to the Sony satellite band such as C band, KU band, KA band. These are bands that go up above UHF.

K. Well, the UHF television operates around the frequency of 500 megahertz, from 400 to 800 approximately, depending on the ~~trowell~~ channel, the number, and KU band is 12 geres which is approximately 20 times higher frequency. Now you see the advantage of high frequencies is that it permits you much more band width because the band width is then a small fraction of the frequency. And the principle of operation is different ____________________ and fine modulator signal and frequency modulation in contrast to amplitude ~~entergen?~~ modulation but it is much more efficient and effective.

I. So really what you are saying is that the higher the frequency, the more channels you have?

K. Right. The more channels you have, yes. It is more difficult to generate high frequency than low frequencies -- the pay off is very high because you have many more channels. Yes. They wouldn't be enough room, simply. The room on UHF--the lower frequency--is exhausted and for instance the C band which is the traditional band for, let's say Bell telephone operations of telephone conversations across the ocean, and in the United States and America, and so on to other continents. This is all filled up. So there no way but the equipment eventually have their limit so we have to move to higher and higher frequencies. For instance, the NASA satellite operates at 20 gigahertz - the planned future NASA communications satellite, so called advance communications satellite operates around 20 gigahertz which is higher than 12 gigahertz which is the commercial television frequency assigned.

I. I might come back to that a little bit later and get into it a little more but right now, let's ask you about what monetary award did you get for the DVT?

K. Oh, I received for this from NASA headquarters, $10,000.00.

I. And I understand you have received other monetary awards and...

K. In computers, yes.

(Third party: Rather than the amount, maybe have him tell what the award was.)

I. Yes. I think maybe what we out to do is mention...

K. Well, I feel very privileged to say that I received more monetary awards for patents in the past and recently then anybody else at NASA. And I have been the first employee of Lewis to receive recent awards of "Inventor of the Year."

I. Now, maybe we can turn to some of those earlier inventions and one of them is what is called the multi stage depress collector and sometime ago you received an award for this also. And basically what this is, from what I understand, is a way to collect electrons so that they are not wasted and send them back to the satellite battery -- so you again gain more efficiency. Could you tell us what is a multi stage depress collector and how is it used?

K. Well, the multi stage depress collector is a passive energy recovery device. That is the electrons which travel through inside of this spring, or helix or staircase or so on, when they leave the actual device, amplifying device, they still have lateral kinetic energy, energy of motion, left in them. Now, this energy would be wasted into heat and although it is such a big premium, so what we do essentially, this motion like a spinning wheel, if I may compare it to that, is slowed down in creating energy. They run against negative potentials and the kinetic energy then returned in the form of current and recharges the battery. Only part of the power is being used. And this saves a lot of power so the battery can be operated much more efficiently.

I. I just wanted to ask if you would like a drink of water...

K. Yes, I would like a glass of water.

(Tape is re-running radio communications between NASA Houston and a returning manned space module.)

SIDE 2

I. The multi stage depress collector is an electron collector, if you want to call it that, and work has been going on for a long time. It's been perfected. Have a lot of good people been involved in this effort?

K. Yes, it was a very vital and relatively large operation over a period of perhaps since the late '60's until now -- almost 20 years. And in the process of this the depressed collector has been perfected to such a degree that now on demand they can be designed with a computer aided design to perform at an efficiency between 80 and 90%, and on the ~~Ø~~ dc beams close to 98%. So, actually they are approaching the limit of possibilities in performance of perfection. And they are extremely useful tools in that they increase the efficiency of these devices for space operation, for avionics, and for electronic warfare and military applications has become very vital. They have been used successfully in deep space operations.

They are being used in space communications satellites, in electronic counter measures, for instance in the operation over Libya they were working very well, and I think it is an important recognition of the quality of the work which my former group has accomplished in that they will be rewarded for the excellence by prestigious ~~High Triple E~~ IEEE recognition in the middle of this year -- in a few months.

IEEE Award

I. ~~High Tr~~iple E is... IEEE

K. It is a ~~group~~ Society of electrical and electronic engineers which is the international, very prestigious organization in this field of science and technology.

I. Before we get into a little bit explanation exactly how this multi stage depress collector or electron collector, if you want to call it that, works, what exactly is an electron?

K. An electron is the sub-atomic particle -- a very tiny one -- the hydrogen atom, for instance, is the smallest piece of stable matter if I may say to this weight -- the smallest atom. And the electron is roughly 2000 times smaller than the hydrogen atom. Compare it with something which people are maybe better familiar with, an electron is probably a billion times smaller than an virus -- small viruses -- and maybe even smaller yet. I am not sure about this but just to indicate the electron is a charged particle and because it is so small it's inertia is extremely small and for this reason it lends itself very well to manipulation with this high frequencies, with this amplitudes and power levels and so it follows that instantly because it is so light...

I. So this is what makes up electricity?

K. Yes. The flow of electrons whether it is in commercial electricity, in your regular wall outlet, or in radio and so on -- everything is full of electrons -- of charges.

I. So the multi stage depressed collector, when you are shooting electrons through it, are you really shooting electricity in a sense through it although there are separate electrons?

K. Oh, yes. Definetely. Because the flow of the number of electrons crossing a certain plane per unit time is electric current. So essentially what we do is the electrons that the depressed collector~~s~~ process, it extracts from them the kinetic energy, the energy of motion and transforms this energy into electric power of the battery. And by doing that essentially the net usage of power from the battery is being reduced. This, of course, increases efficiency. So in other words, I begin to operate with a certain amount of funds and after I do the operation I have money left over. And I transfer it back to the original source. So just savings some of the expenses.

I. How does the multi stage depressed collector work?

K. It could perhaps be compared to a water fountain that ejects ~~radically~~ upwards many droplets of water. Now the water droplets move upwards on a kind of a parabolic trajectory and at one point, at the apex of the trajectory, they have virtually zero velocity. They do ~~not~~ no longer move upward. ~~They begin then just~~ The upward motion is converted into a downward motion. At that time, they land on plates that are present and are collected without splashing to a zero velocity. At that time they have no kinetic energy and all the energy has been transformed into electric power. This gain in this electric power of this electrodes is the principle operation of the collector.

I. Does that mean the electrons are actually adding power back into the battery?

K. Right. They are being returned to the battery. Yes. Unused.

I. In what satellite was this electron collector or multi stage depressor collector first used?

K. Yes. It was first used in communication technology satellite that was a 200 watt -- this was the largest and perhaps still is -- the largest television satellite put up into space in the early '70's. It was a common project between United States and Canada. It served to the development of an efficient space satellite for television signals to illuminate large areas of Canada where they have no ground receiving stations and television stations and over the United States to areas such as Idaho, the Rocky Mountains, in desolated areas where it is very difficult to receive normal television signals; and it is not commercially profitable for stations to operate because they have very few customers.

I. Is this direct satellite broadcast? And could you define that?

K. Well, yes it is. The 200 watt power is so strong that by installing a small size antenna on a roof of a house or the place you wish to receive it like a school, hospital, etc. you can receive with very inexpensive means, with very inexpensive ground amplifier the television from space directly without going through a television station. And this was very important because many of the education programs in this program are being processed with a television satellite and instrumental for the success of this television satellite CTS in the early '70's was the high efficiency. You know, if you had a 200 watt tube and the efficiency were 10 or 20% you would have a kilowatts of power which would make the satellites very, very expensive because solar cells are not only expensive but also very large and bulky. It requires a huge rocket to put it up into orbit. So it doesn't become finally very feasible or attractive. Now, by making this tube over 50% efficient, which was a world's record at that time, and still I believe is, for space satellite tube of this kind, many things became financially justified.

I. The multi stage depressed collector or electron collector combined with the DVT, is that being used today?

K. Yes it is. As a matter of fact the multi stage depress collector has become an inherent part. Every modern tube has it -- every one -- with no exception. And, DVT, of course, performs a lot of functions. It is not only improving the efficiency far beyond what was available before, but also there are things to the signal like we talked linearity. And the hard limiting characteristics that the depressed collector couldn't do. One is an active device and the other is a passive device. The passive device conserves power in that it recovers the energy that would otherwise have been wasted.

I. The direct satellite broadcast to the home or direct broadcasting, if you want to call it that, is being used, I believe, no in Europe.

K. Oh, yes.

I. Also, satellite slots for direct satellite broadcasting, I believe, have been allocated in this country...

K. Yes. They have been.

I. Does the multi stage depress collector, perhaps in combination with the DVT, does that enable or make possible direct satellite broadcast as feasible?

K. Oh, yes. Of course, it was feasible before that, but now the number of signals processed and the quality of signals and the cost of operation is much less. And if you observe, for instance, the trans-Atlantic telephone conversations -- if you call Europe or Japan -- are a lot cheaper now than they were ten years ago. Everything else is going up in price but this is going down. And this is going down because of such innovations.

I. We talk about the commercial use of space, making medicines in space, perhaps, new alloys.... How does the communication business... Is it really the true business of space right now? How could you compare it to the other industries that possibly are going to be taking place in space?

K. Well, communication, of course, is always the necessary link because once you have something going in space you would like to know WHAT is going on, And this has to be traveled back to earth. So the communication is an inherent link between various stations of operation which will be research centers on the earth or factories that process something and space. They do have monitors now and computer controlled devices and recording devices that record what is going on, monitoring devices and transmit this back to earth. This requires a large operation capable of massive bit ratios. Many of these bits per second -- you can move now into the region of gigabits which means a billion bits.

I. What are some of the other uses of electron collectors or multi stage depressed collectors it is technically called? Are these used also to save electricity for some television stations?

K. Oh, yes. NASA together with the Varian Corporation and with the National Assoc. of Television Broadcasters have signed an agreement in which Varian utilizing this device and the concept will improve the UHF transmitting Klystrons, ~~Klystrons that~~ operate the level depending on the station operating between 10 and 100 kilowatts. And because of the particular mode of operation they were very inefficient. The typically efficient of this Klyrstron was not more than 15% -- between 10 and 15.

I. Klystron -- that is the broadcasting tube that makes the signal go out?

K. Right. This is the broadcasting tube that send the signal into the antenna of the television station would then spread it to the users. And because of the old-fashioned design by tradition the operation is very inefficient. In other words, a lot of electric ~~enactie~~ power is being wasted to such a degree that essentially water is being boiled. By boiling water, you dissipate the unused energy and this is not only undesirable but also very expensive and by combining this klystron ~~license~~ with the multi stage depress collector the efficiency will be at least doubled. So the cost of operation of television stations such as channel 25 PBS, especially the public broadcasting stations who hurt for money by virtue of the operation from private funds instead of being supported by commercials. They need this most. This will cut the cost of operation by a factor of 2.

I. Let's turn back to the satellites for a minute. We talked about the various bands in the gigahertz which are the wavelengths, I guess. How can you describe the various wavelengths? For example, I know ... in inches or yards? How big are the band widths? We have the C band which is the original satellite band, as I remember. The KU band which is the CTS satellite, the KA band which is.... Could you go through those? And how far are we going to go up with these band widths?

K. Well, the reason that we go up as I mentioned before is that the frequency band, the lower frequency range are being overcrowded. These last frequency capacities, so to say, and all of this has been allocated and used. And in order to avoid interference, you have to move to higher frequency bands. So the so called X band frequency which is around 8 gigahertz is used mainly for military applications, the KU band 12 gigahertz is next television broadcasting allocation, and then the 20 hertz band has been allocated for fixed location communication -- from one fixed place to another fixed place. For instance, one bank in the United States transfers data, financial operations, etc., Wall Street, the Market, from one place to another and you need more and more because this information becomes very large, you need more and more band width to process this huge bits or number of operations or information.

I. Dr. Kosmahl early invented the plasmic accelerator which is a form of an electric rocket which does not use a poisonous substance like Mercury, or Cecium as a propellant but used zenon and crypton ions which are spued out the end of this rocket to produce a rocket thrust. Dr. Kosmahl, what is an electric rocket?

K. Well, an electric rocket is a propulsion device and its different ~~to~~ from a chemical rocket that burns fuel and ejects like a jet in a plane. The hot fuel with certain velocity which is limited, to propell to move large payloads, an electric rocket ejects tiny particles. The particles are much more tiny than the amount of gas spewed out in chemical rockets. But the speed of the electrically charged particles that are ejected is very very high. So it is known as high specific impulse and it has a lot of advantages because the amount of fuel used is much smaller than in huge rockets like Saturn, for instance, that propel the Voyagers to the moon. In many missions it is not required to arrive at a certain target, Instantly, you have more time and you would like to conserve energy and fuel. And that is the occasion where you use these electric rockets. Electric rockets exist in two fundamental forms: one is the ~~iron~~ ion engines that utilize cesium ~~cezur?~~ or mercury which is undesirable and also not available in large amounts. Now the plasma rockets can use gases that are not poisonous and available in much higher amounts. And I analyzed one particular type of a plasma rocket or plasma engine or plasma accelerator, is all synonymous ~~in its description~~ and working principle which utilizes microwave power. The plasma is an ionized gas. The gas is contained in a magnetic ~~fuel~~ field -- like suspended. And then the microwave power, what it does, in the ionized plasma there are electrons which are negative particles and ions. Now the electrons are much ~~better~~ lighter than the ions and the inertia is much less than that of the ions. The ions are like heavy boulders. Electrons are like tiny particles of sands for instance for comparison and they are being spun ~~off~~ up in the magnetic field to a very high circular velocity. Now the magnetic field then is decreased in magnitude and finally to very small levels and what happens is the rotation spinning motion of the electrons is transferred by virtue of the decreasing molecular field into a longitudinal motion. So electrons require very fast longitudinal motion and they move out and because the plasma has to stay neutral on the average, deposited particles are being dragged along. And they approach much higher velocities -- what we called before, the specific impulse in chemical rockets -- and this is being then used, or is planned to be used in space, for certain missions like orbit transfers and similar to Mars where you have a payload and you don't have very much power and you utilize the electric engine because you try to increase your useful payload instead of carrying fuel -- tremendous amount of fuel, you carry less fuel but use more time.

I. The electric rocket cannot blast off from the earth and can run for a very long time and accelerate very slowly. Whereas a chemical rocket usually spends all its fuel in a couple or few minutes (five minutes).

K. That's right.

I. Why use an electric rocket? What is it important? Or a plasma rocket? To use these in space work.

K. Well, essentially the difference between the chemical rockets and the electric rockets is this one. The chemical rockets burns huge amounts of fuel -- hundreds of tons. Within five minutes, for instance, the operation is completed and then you achieve a very high rate of propulsion, of acceleration in a very short time. This you must do on several occasions. Like lifting, for instance, Saturn C5 rocket going to the moon. Or ballistic missiles or whatever. The other occasion where you would like to conserve the amount of fuel and instead of completing the process of acceleration in such a short time like five minutes, you expend for this a year or two or three. You propel at a very small rate but you use almost no fuel. And this is for very many missions an advantage.

I. So you get more miles per gallon?

K. Right. But lots more time. You are trading the time of acceleration long, slow acceleration but over much longer time and you still get to the target with much less fuel than in the case of chemical departure.

I. In long flights perhaps to Mars, for example, I suppose it is possible that the electric rocket may actually catch up and surpass the chemical rocket.

K. Yes, very definitely. Because it is not useful to carry that much fuel with you.

I. What is a plasma and how does it relate to the electric rocket? Is a plasma like what you might find in a florescent light bulb or a neon light bulb, for example? What is a plasma?

K. Well, plasma in general is an ionized gas. Gas as such all atoms that are common in nature are neutral. They are composed of electrons and of positive charges. Now, by the process of ionization we can separate the electrons from the positive charges. And then we talk about the plasma. Plasma exists, for instance, if you look at polar lights and so on this is a plasma. And also in a florescent light, there is also a lot of plasma present. Plasma is also, let's say, in quartz lamp. The old fashioned quartz lamp. People used in medicine sometimes and for getting brown quickly. I'm afraid it is not a very healthy way. And here we artificially ionize gas so we separate the negative and positive charges and then we can operate on the electrons much more easily than on the positive charges. And the requirement for neutrality then drags the positive charges along with the electrons. And this is a very elegant process. It is being pursued now by the California Institute of Technology for future space missions.

I. So you handle plasma, or a gas, which is ionized. Then you take the microwave radio energy and you go around it and this speeds up the electrons and then what happens?

K. The electrons are being spun up to a very high circle of motion with very high velocity and when they acquire the maximum velocity, this is all happening in the microwave field. Now, when they acquire maximum velocity, all the power has been transferred, then we stop the magnetic field and this causes, it is too difficult to describe why, but this causes the electrons to be expelled, so to say, from the magnetic field. They are thrown out at high velocity and they drag the ions along with them and this causes thrust or propulsion.

I. So that's the stuff that comes out of the rear of this microwave rocket.

K. That's right. It's a neutral gas.

I. About how much thrust do you have with these rockets?

K. Oh, the thrust can be measured....I mean, we talk about in missiles and so on, you have hundred thousands of pounds and here you talk about milipounds which is one thousands of a pound, something like this. This would be very tiny.

I. Some of the uses you've mentioned, for example one is orbital transfer. I take it that is where you take a satellite from a low earth orbit -- a few hundred miles -- and put it farther up.

K. Right.

I. Could you say that again, sir, like I did?

K. Well, essentially, the chemical rocket uses a robust, brutal force and so on to produce a very high rate of acceleration instantly. So, ah, in other words, to push something from one point to another point. You can accomplish the same thing by pushing very slowly with very gentle thrust, with very light acceleration over a very long period of time and still arrive at the same target but using much less fuel.

I. Thank you very much.